AD-A168 459 DESIGN CALCULATIONS OF THE HURRICANE MOORINGS AT NAVAL STATION MAYPORT FL..(U) NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON DC CHESAPEAKE.. C A HUBLER DEC 84 1/2

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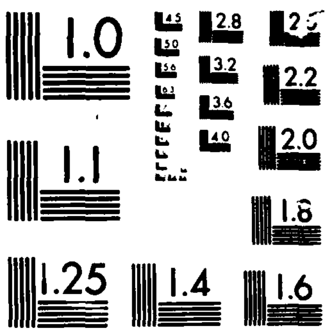

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DESIGN CALCULATIONS OF THE
HURRICANE MOORINGS AT
NAVAL STATION, MAYPORT, FLORIDA
FPO-1-84 (46)
December 1984

Ocean Engineering

CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON NAVY YARD
WASHINGTON, DC 20374

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DESIGN CALCULATIONS OF THE HURRICANE MOORINGS AT NAVAL STATION, MAYPORT, FLORIDA

FPO-1-84 (46)

December 1984

by

C. Allan Hubler

APPROVED BY:

Shun C. Ling

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OCEAN ENGINEERING & CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, DC 20374

Summary

These design calculations are for specialized fleet moorings which will be installed for the Naval Station (NAVSTA) Mayport, Florida. It was requested that Chesapeake Division, Naval Facilities Engineering Command, Ocean Engineering and Construction Project Office, design and install the moorings for the NAVSTA. These fleet moorings are in a specialized category because they will be used to moor vessels during a hurricane. There will be three moorings that will accommodate 22 crafts ranging in size from LCM to YON that are assigned to the NAVSTA, (see pages B-2, B-3, and B-4).

The location of the moorings is on the east bank of the St. John River, west of Blount Island, (see page B-6). Bathymetry of the anchorage area and soil conditions at the anchor location has to be confirmed by a site survey. The vessels at moor under certain environmental conditions will swing into the channel. Informal discussions with federal and state agencies implied that there would be no denial for installation, however this needs to be formalized by submitting applications for construction to the appropriate agencies.

Because the moorings are a survival type, the 100-year extreme event will be used for the design criteria. Therefore, highest, fastest mile design wind will be 80 miles per hour. The current will be 1.5 knots, (see pages A-3 and A-5). These environmental events generated a maximum static hawser load of 32 kips (see page C-36) and a maximum dynamic hawser load of 55 kips, (see page D-4).

The final design is a free-swing riser type mooring. Each mooring will have four ground legs consisting of 2 inch chain so that each opposing leg can be proof loaded and verified to the design load. The anchors will be Navy stockless with stabilizers and with the flukes fixed open to 50 degrees. There is a 10 kips sinker connected to the ground ring. The mooring systems will be cathodically protected with zinc anodes.

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These design calculations are for specialized fleet moorings which will be installed for the Naval Station (NAVSTA) Mayport, Florida. It was requested that Chesapeake Division, Naval Facilities Engineering Command, Ocean Engineering and Construction Project Office, design & install the moorings (Con't)

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CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Station: E S R: Contract:
Calcs made by: C. Hull date: Calcs ck'd by: NMSealing date: 30 Nov 84	Calculations for:

I Environmental Design Criteria

1. Design Wind

The design winds for this hurricane mooring were derived from raw wind data from the old Jacksonville Airport which has about 30yrs of data. The airport is within 5 miles of the mooring site so this wind data is valid to use in establishing the design wind. Because the moorings are survival type the 100yr return event will be used. The National Climatic Data Center (NCDC) did an extreme event analysis for tropical and non-tropical storms in 8 compass directions. The weibull distribution was used for the analysis. The fastest mile wind speeds are given below in mph. The highest wind speeds from any population are used as the design winds.

	Mixed Distribution	Non-Tropical Dist.	Tropical Dist.	Design Winds
N	70	62	80	80
NE	59	56	61	61
E	72	50	79	79
SE		51		51
S		56		56
SW		56		56
W		48		48
NW		48		48

CHESAPEAKE DIVISION **Naval Facilities Engineering Command NDW** **DISCIPLINE**	**PROJECT:** ____ **Station:** ____ **E S R:** ____ **Contract:** ____
Calcs made by: [illegible] **date:** ____ **Calcs ck'd by:** MVS **date:** ____	**Calculations for:** ____

Because the crafts using the moorings are of light tonnage, the mooring response to the wind will be around the 30 second wind duration time. NCDC gave the fastest mile wind speed which has a varying duration equal to the time it takes for the wind to travel one mile. Therefore all NCDC wind speeds had to be converted to 30 second duration wind speeds. Below is an example of the conversion for an 80 mph wind.

Duration of 80 mph fastest mile wind

$$\frac{3600 \ sec/hr}{80 \ mi/hr} = 45 \ sec/mi$$

Use figure 1.1 to set up proportions using the gust ratio for the 30 and 45 second duration.

$$(\text{Fastest mile speed}) \times \left(\frac{30 sec. \text{ Gust Ratio}}{45 sec \text{ Gust Ratio}}\right) = 30 sec \text{ Wind Speed}$$

$$80 \ mph \times \left(\frac{1.32}{1.27}\right) = 83 \ mph$$

Now convert mph to ft./sec by multiplying by 1.467

$$83 \ mph \times 1.467 = 122 \ ft/sec$$

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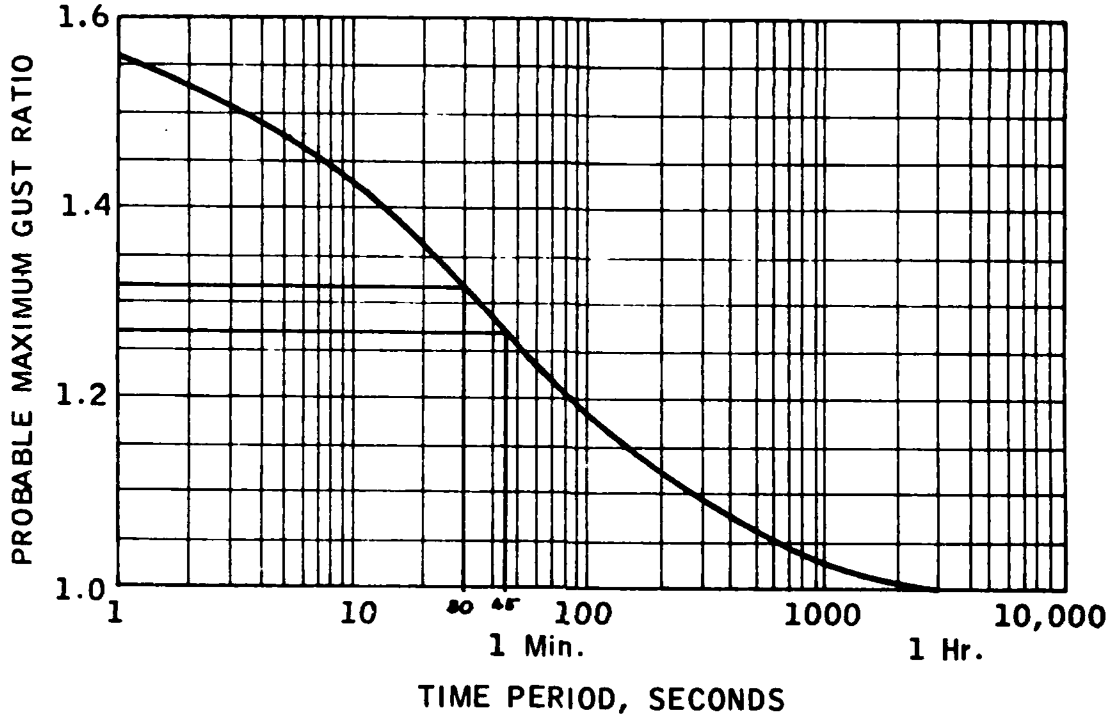

Figure 1.1 - RATIO OF PROBABLE MAXIMUM AVERAGE (GUST) WIND VELOCITY FOR PERIOD TO ONE HOUR AVERAGE
From "Guidelines for Deepwater Port Single Point Mooring Design" NTIS AD/A-050-182

The Design wind speed and direction are given below:

N - 122 fps	S - 86.9 fps
NE - 89.5 fps	SW - 86.9 fps
E - 120 fps	W - 75.6 fps
SE - 79.6 fps	NW - 75.6 fps

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Design Current

The design currents for the moorings are controlled by the St. John's river tidal current. The current direction will be controlled by the river channel which is NNE by SSW. The current speed for the moorings was derived from the St. John's inlet velocities. NAVFAC DM-26 states an inlet velocity of 3 knots and the 1984 NOAA Tidal table states that a maximum ebb velocity is 3.1 knots for Mayport inlet. These inlet velocities need to be translated to the mooring site. This was done by using the US Army Engineer Waterways Experiment Station hydraulic model investigation. This study titled "Mayport - Mill Cove Model Study" (TR-HL-79-12) had a verification phase which included 2 days of real time velocities measurement taken close to the mooring site and at the inlet. Figure 1.2 shows stations 1 and 2 which were used to proportionate the inlet velocity to the mooring site. The analysis is shown below:

From WES Model Study

Station 1 - Max. recorded velocity - 4.5 fps

Station 2 - Max. recorded velocity - 2.2 fps

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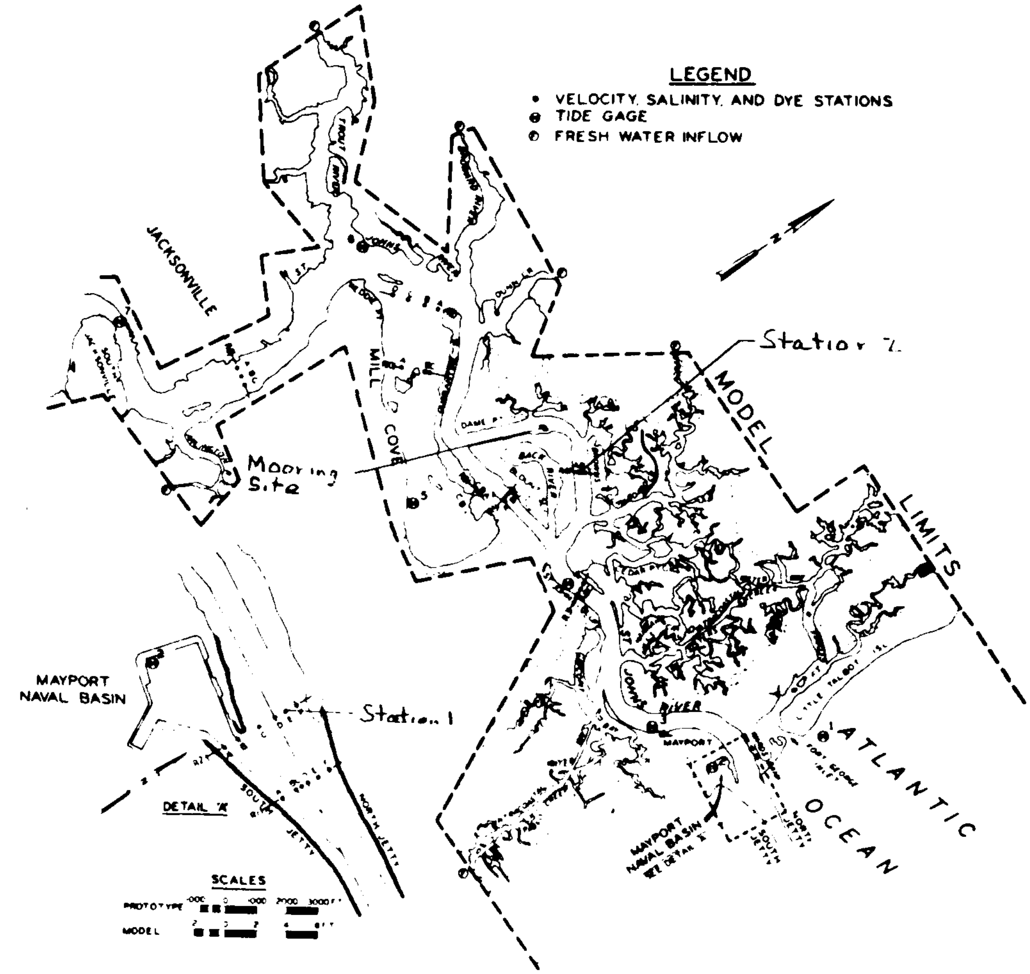

MODEL LIMITS AND PROTOTYPE STATION LOCATIONS

Fig 1.2 - Excerpt from Mayport-Mill Cove Model Study

Design Current = Inlet current × $\frac{\text{Current @ Station 1}}{\text{Current @ Station 2}}$

$= 3.1 \text{ knot} \times \frac{1.68 \text{ fps}}{1 \text{ knot}} \times \left(\frac{2.2}{4.5}\right)$

$= \underline{2.5 \text{ ft/sec}}$ NNE and SSW

CHESAPEAKE DIVISION	PROJECT:
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Calcs ck'd by: WAS date:	

II Mooring Layout and Location

There will be three mooring to accomodate 22 vessels at the NAVSTA Mayport. Below is the list of vessels:

1. YD-188	9. YON-259	17. YTB-3
2. YC-1444	10. YON-261	18. YTB-4
3. YD-204	11. YON-271	19. YTB-5
4. YON-88	12. YON-283	20. LCM-6-1
5. YC-360	13. YON-100	21. LCM-6-2
6. YC-1482	14. YON-258	22. YTL-30
7. YC-1884	15. YTB-1	
8. YC-1553	16. YTB-2	

These vessels (20–22) will be lifted out of water and placed on the crane barges.

The moorings will be used by the vessels listed above and no others, and will be used only during a hurricane. The NAVSTA's Standard Operating Procedure for hurricane warning has a layout of which vessels used which moorings. These layouts are shown as Moorings A, B and C.

Figures 2.1, 2.2 and 2.3 show the barges rafted together. This will be done with wire rope and there will be sea cushion type fenders used between the vessels. The size required is 4 ft dia. x 7.4 ft long and 2 for each barge to barge face.

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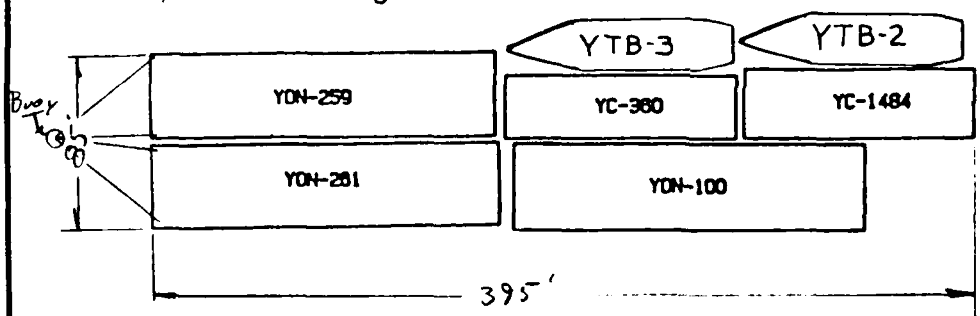
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: [illegible] date:	Calculations for:
Calcs ck'd by: WMS date:	

Mooring B

Vessels	Length	Beam	Draft	∇	Aw Front	Aw Side	Awet
1. YON 259	165	40	8	1445	610	2520	9,880
2. YON 261	165	40	8	1445	610	2520	9,880
3 YC 360	110	31	4	350	330	1090	4538
4. YON 100	165	35	8	1270	534	2520	8975
5. YC-1484	110	32	8	694	330	1090	5792
6. YTB-2	105	28	13	320	560	1790	
7. YTB-3	105	28	13	320	560	1790	

Layout - Figure 2.2



Total Displacement - 5844 long tons

Area front - 1220 ft^2 + 15% sheltering (barges)
Area Side - 2715 ft^2 + 11.7% sheltering (barges)

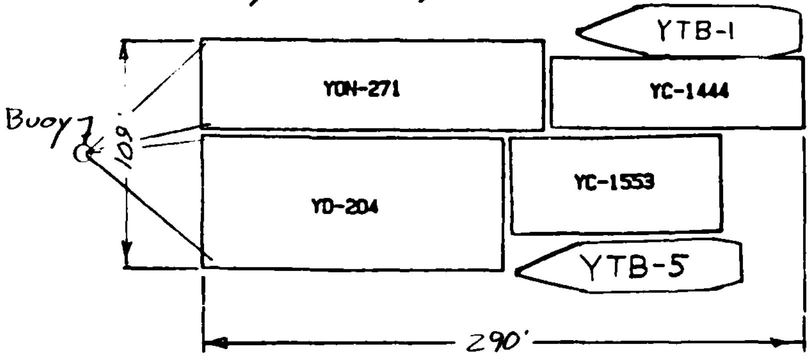
Wet Surface Area (barges) - 39,065 ft^2

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Station: E S R: Contract:
Calcs made by: date: Calcs ck'd by: MAS date:	Calculations for:

Mooring C

Vessels	Length	Beam	Draft	∇	A_wFront	A_wSide	Awet
1. YD-204	144	64	6	1064	500	1800	11,712
2. YON-271	165	40	8	1445	610	2520	9,880
3. YC-1444	120	33	8	755	450	1640	6408
4. YC-1553	110	48	4	210	630	1400	6544
5. YTB-5	105	28	13	320	560	1790	
6. YTB-1	105	28	13	320	560	1790	

Layout Figure 2.3



Total Displacement - 4114 long tons

Area Front 1410 ft^2 + 15% sheltering (barges)
Area Side 4160 ft^2 + 15% sheltering (barges)

Wet Surface Area (barges) = 34,544 ft^2

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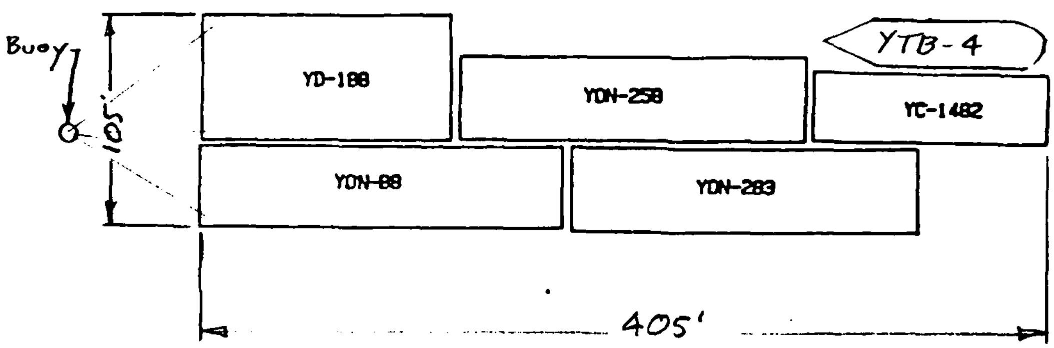
CHESAPEAKE DIVISION **Naval Facilities Engineering Command NDW** **DISCIPLINE**	**PROJECT:** [illegible] **Station:**
Calcs made by: Al H..bler **date:** 1/20 **Calcs ck'd by:** WMS **date:**	**E S R:** **Contract:** **Calculations for:** Loading of Moorings A B & C

Mooring A

Vessels	Length	Beam	D	∇	A_w Front	A_w Side	A_{wet}
1. YD-188	120	60	8	637	800	1600	10,080
2. YON-88	174	40	8	1460	800	1600	10,384
3 YON-252	165	40	8	1445	610	2520	9,880
4. YON 283	166	40	9	1506	610	2520	10,348
5. YC1482	110	32	8	694	330	1090	5,792
6. YTB-4	105	28	13	320	560	1790	

Layout - Figure 2.1



Total Displacement - 6062 long tons

Area Front - 1600 ft^2 + 15% sheltering (barges)
Area Side - 5210 ft^2 + 15% sheltering (barges)

Wet Surface Area (barges) - 46,484 ft^2

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CHESAPEAKE DIVISION	PROJECT:
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: date:	Calculations for:
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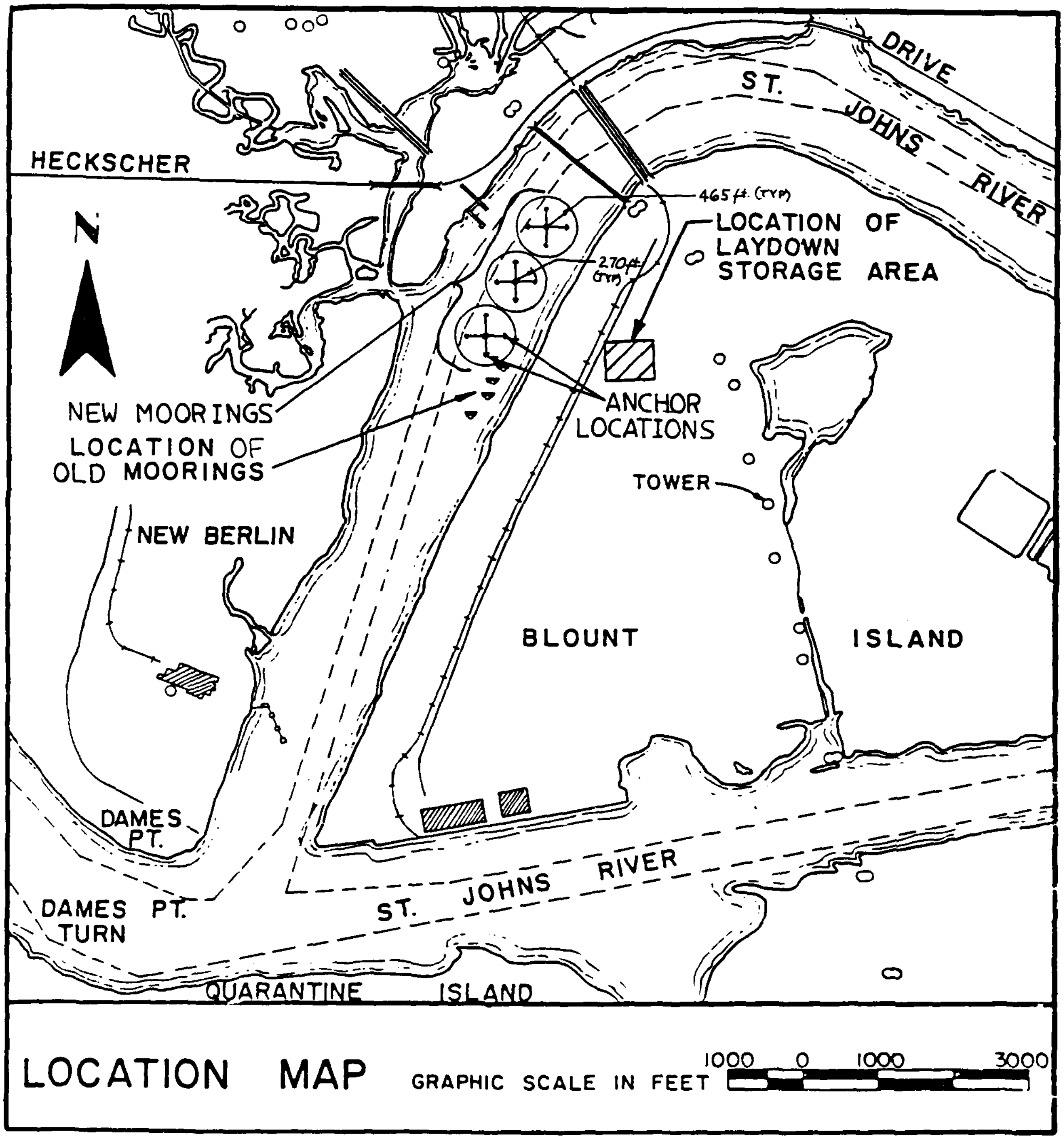
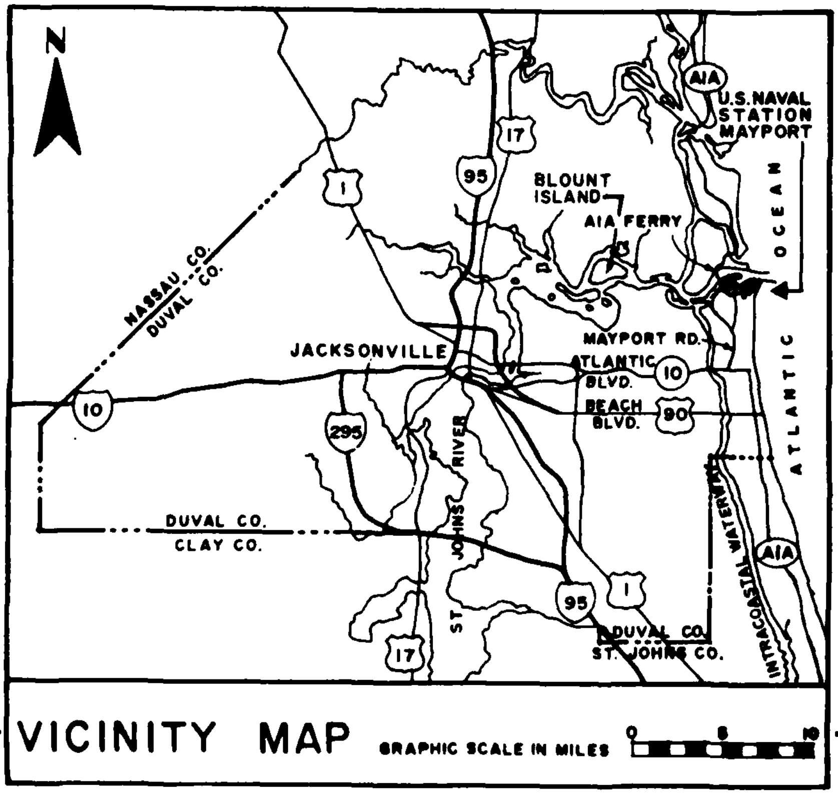


Figure C.5

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ______ Station: ______ E S R: ______ Contract: ______ Calculations for: ______
Calcs made by: C Hall date: ______ Calcs ck'd by: WMS date: ______	

The location of the moorings are on the West side of Blount Island as shown in the vicinity map below and the location map on the following page. The old moorings, which are being removed are bow/stern type. This type of mooring has large lateral forces for which large anchors had to be used to restrain this force. Unfortunately there is not enough soil for the anchor to hold. A free-swing type mooring will be designed for the barges and the vessel's watch circle and anchor location can be seen in figure 2.5.



VICINITY MAP GRAPHIC SCALE IN MILES 0 5 10

Figure 2.4

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CHESAPEAKE DIVISION	PROJECT:
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: [illegible] date:	Calculations for:
Calcs ck'd by: NMS date:	

III Static Environmental Loading

The present moorings had a bow/stern type configuration. In talking with the NAVSTA Public Works, Army Corps of Engineers, U.S. Coast Guard Jacksonville and the Jacksonville Port Authority, they all indicated that a free-swing type mooring with the vessel swing radius into channel will not cause any problems because the mooring will only be used during a hurricane.

The procedure for designing a free-swing mooring for static loading is given in NAVFAC DM-26.5 - 95% submittal. The procedure is simple but tedious and requires iterating the vessel's position until the moments acting on the vessels are zero. The flow diagram for the procedure is given on the next page. All figures, graphs and tables from this page on to page C-22 are taken from DM 26.5 - 95% submittal.

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DISCIPLINE	E S R: Contract:
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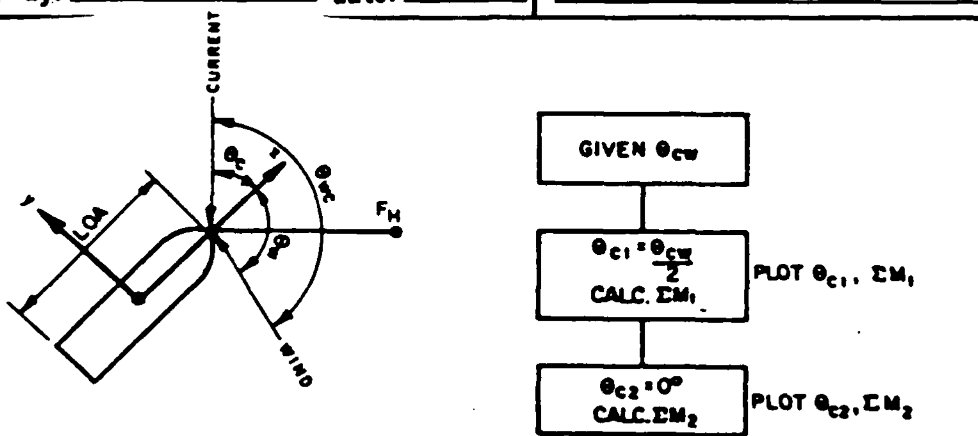

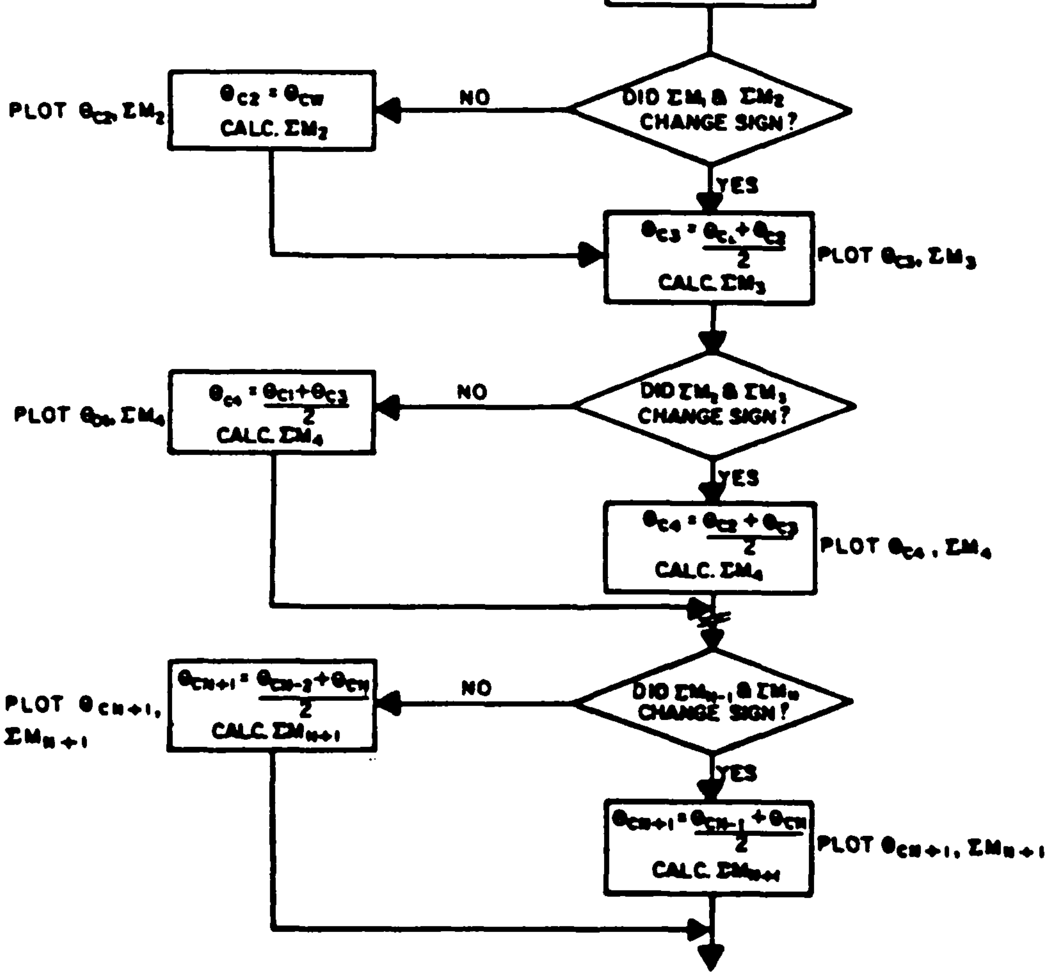

NOTE: CONTINUE PROCESS UNTIL DIFFERENCE BETWEEN θ_{CN+1} AND θ_{CN} IS SMALL OR UNTIL EQUILIBRIUM ANGLE CAN BE DETERMINED FROM GRAPH SHOWN IN FIGURE 66

Figure 3.1

CHESAPEAKE DIVISION	PROJECT:
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Calcs made by: date:	Calculations for:
Calcs ck'd by: WMS date:	

The following are the calculations for environmental loads on Mooring A which will have the highest loads due to the size and number of vessels using the mooring. The 5 barges in this mooring will be grouped as one vessel. The length is the total length of the longest barges plus 5 ft. added between the barges for fender cushions. The same method is used to calculate the beam. The YTB will be calculated separately and then those forces will be added to the barge group.

The figure 3.2 on the next page shows the coordinate system and the nomenclature for the Wind and Current loads.

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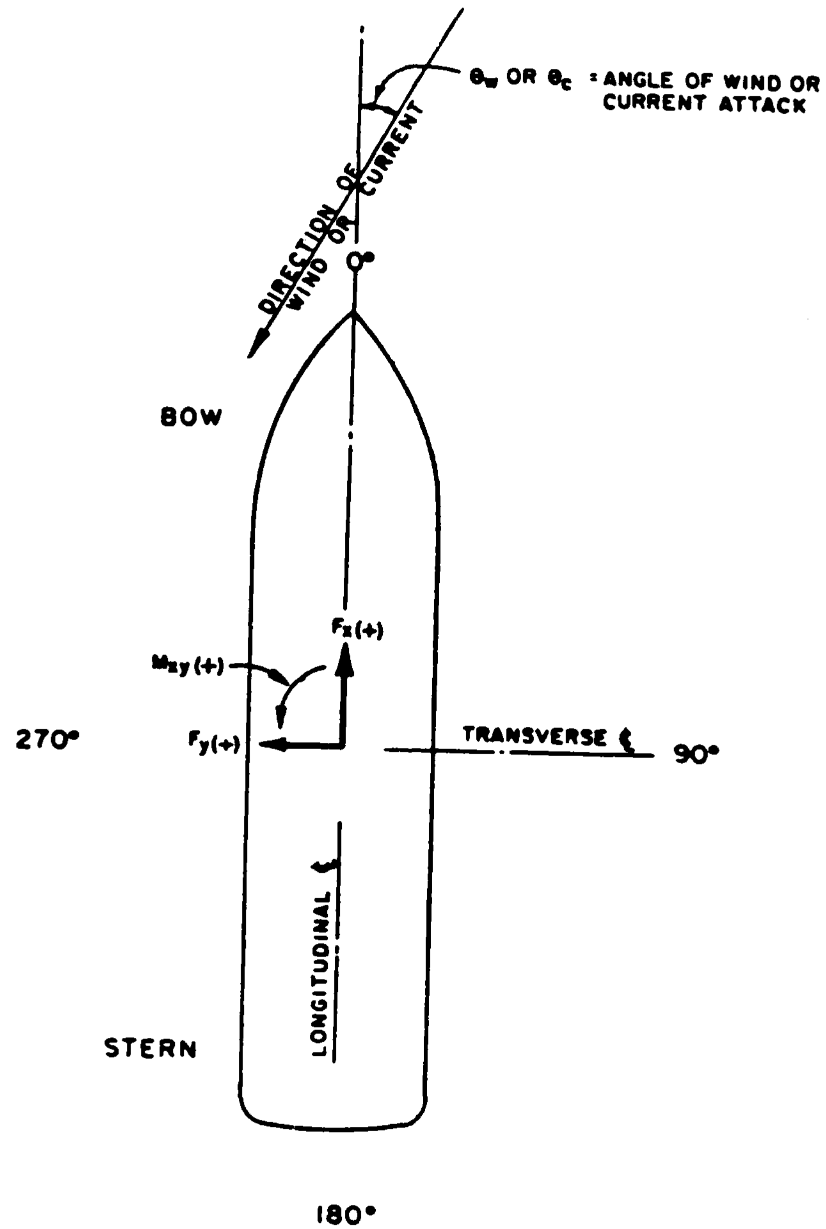
CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ____ Station: ____ E S R: ____ Contract: ____
Calcs made by: R. Hall date: ____ Calcs ck'd by: WMS date: ____	Calculations for: ____



NOTE: DEGREES REFER TO θ_w OR θ_c

Figure 3.2

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CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Station: E S R: Contract:
Calcs made by: [illegible] date: Calcs ck'd by: WMS date:	Calculations for:

(a) Lateral wind load. Lateral wind load is determined using the following equation:

$$F_{yw} = \frac{1}{2}\rho_a V_w^2 A_y C_{yw} f_{yw}(\theta_w)$$

WHERE: F_{yw} = lateral wind load, in pounds

ρ_a = mass density of air = 0.00237 slugs per cubic foot at 68°F

V_w = wind velocity, in feet per second = varies

A_y = lateral projected area of ship, in square feet = 5210 ft²

C_{yw} = lateral wind-force drag coefficient

$f_{yw}(\theta_w)$ = shape function for lateral load

θ_w = wind angle = varies

The lateral wind-force drag coefficient depends upon the hull and superstructure of the vessel:

$$C_{yw} = 0.92\left[\left(\frac{V_S}{V_R}\right)^2 A_S + \left(\frac{V_H}{V_R}\right)^2 A_H\right]/A_y$$

WHERE: C_{yw} = lateral wind-force drag coefficient

V_S/V_R = average normalized wind velocity over superstructure

A_S = lateral projected area of superstructure only, in square feet = 1000 ft²

V_S = wind velocity on superstructure

V_H/V_R = average normalized wind velocity over hull

A_H = lateral projected area of hull only, in square feet = 4210 ft²

A_y = lateral projected area of ship, in square feet

V_R = reference wind velocity at 33.33 feet above sea level

V_H = wind velocity on hull

The values of V_S/V_R and V_H/V_R are determined using the following equations:

$$\frac{V_S}{V_R} = \left(\frac{h_S}{h_R}\right)^{1/7}$$

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$$\frac{V_H}{V_R} = \left(\frac{h_H}{h_R}\right)^{1/7}$$

WHERE: V_S/V_R = average normalized wind velocity over superstructure

h_S = average height of superstructure, in feet = 45 ft.

h_R = reference value of windspeed (33.33 feet)

V_H/V_R = average normalized wind velocity over hull

h_H = average height of hull, in feet = 4.5 ft

$$\frac{V_H}{V_R} = \left(\frac{4.5}{33}\right)^{1/7} = .75 \quad , \quad \frac{V_S}{V_R} = \left(\frac{45}{33}\right)^{1/7} = 1.045$$

$$C_{yw} = .92\left[1.045^2(1000) + .75^2(4210)\right] / 5210 = .611$$

The shape function for lateral load, $f_{yw}(\theta_w)$, is given as:

$$f_{yw}(\theta_w) = \frac{+\left(\sin\theta_w - \frac{\sin 5\theta_w}{20}\right)}{1 - \frac{1}{20}}$$

WHERE: $f_{yw}(\theta_w)$ = shape function for lateral load

θ_w = wind angle

$$F_{yw} = \tfrac{1}{2}(0.00237)\, V_w^2 (5210)(.611) \frac{\sin\theta_w - \frac{\sin 5\theta_w}{20}}{0.95}$$

$$3.772\, V_w^2 \frac{\sin\theta_w - 0.05\sin 5\theta_w}{0.95}$$

15% is added to account for the sheltering.

$$F_{yw} = 4.338\, V_w^2 \left(\frac{\sin\theta_w - 0.05\sin 5\theta_w}{0.95}\right)$$

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CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Station: E S R: Contract:
Calcs made by: date: Calcs ck'd by: AMS date:	Calculations for:

(b) Longitudinal wind load. Longitudinal wind load is determined using the following equation:

$$F_{xw} = \frac{1}{2} \rho_a V_w^2 A_x C_{xw} f_{xw}(\theta_w)$$

WHERE: F_{xw} = longitudinal wind load, in pounds

ρ_a = mass density of air = 0.00237 slugs per cubic foot at 68°F

V_w = wind velocity, in feet per second

A_x = longitudinal projected area of ship, in square feet $= 1600 ft^2$

C_{xw} = longitudinal wind-force drag coefficient

$f_{xw}(\theta_w)$ = shape function for longitudinal load

The longitudinal wind-force drag coefficient varies according to vessel type and characteristics. Additionally, a separate wind-force drag coefficient is provided for headwind (over the bow: θ_w = 0 degrees) and tailwind (over the stern: θ_w = 180 degrees) conditions. The headwind (bow) wind-force drag coefficient is designated C_{xwB} and the tailwind (stern) wind-force drag coefficient is designated C_{xwS}.

Because the barge group has the same shape over the bow or stern, $C_{xwB} = C_{xwS} = 0.7$

Longitudinal shape function, $f_{xw}(\theta_w)$, differs over the headwind and tailwind regions. The incident wind angle that produces no net longitudinal force, designated θ_{wz} for zero crossing, separates these two regions. The barge group has a $\theta_{wz} = 90°$.

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Ships with distributed superstructures are characterized by a "humped" cosine wave. The shape function for longitudinal load is:

$$f_{xw}(\theta_w) = \frac{-\left(\sin\gamma - \frac{\sin 5\gamma}{10}\right)}{1 - \frac{1}{10}}$$

WHERE: $\gamma_{(-)} = \left(\frac{90°}{\theta_{wz}}\right)\theta_w + 90°$ for $\theta_w < \theta_{wz}$

$\gamma_{(+)} = \left(\frac{90°}{180° - \theta_{wz}}\right)\theta_w + \left(180° - \frac{90°\ \theta_{wz}}{180° - \theta_{wz}}\right)$ for $\theta_w > \theta_{wz}$

As explained above, use $360° - \theta_w$ for θ_w when $\theta_w > 180°$.

$$\gamma_{(-)} = \frac{90°}{90°}(\theta_w) + 90 = \theta_w + 90°, \quad \theta_w < \theta_{wz}$$

$$\gamma_{(+)} = \left(\frac{90°}{180° - 90°}\right)\theta_w + \left(180° - \frac{90°(90°)}{180° - 90°}\right)$$

$$= \theta_w + 90° \qquad \theta_w > \theta_{wz}$$

$$F_{xw} = \tfrac{1}{2}(0.00237)V_w^2\,1600(.7)\ \frac{-\left(\sin\gamma - \frac{\sin 5\gamma}{10}\right)}{.9}$$

$$= 1.327V_w^2\left(-\left(\frac{\sin\gamma - .1\sin 5\gamma}{.9}\right)\right), \quad \gamma = \theta_w + 90°$$

15% is added to this force to account for sheltering.

$$\underline{\underline{F_{xw} = 1.526\ V_w^2\left(-\left(\frac{\sin\gamma - 0.1\sin 5\gamma}{0.9}\right)\right), \quad \gamma = \theta_w + 90°}}$$

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(c) Wind yaw moment. Wind yaw moment is calculated using the following equation:

$$M_{xyw} = \frac{1}{2} \rho_a V_w^2 A_y L C_{xyw}(\theta_w)$$

WHERE: M_{xyw} = wind yaw moment, in foot-pounds

ρ_a = mass density of air = 0.00237 slugs per cubic foot at 68°F

V_w = wind velocity, in feet per second = varies

A_y = lateral projected area of ship, in square feet = 5210 ft²

L = length of ship - 405'

$C_{xyw}(\theta_w)$ = normalized yaw-moment coefficient

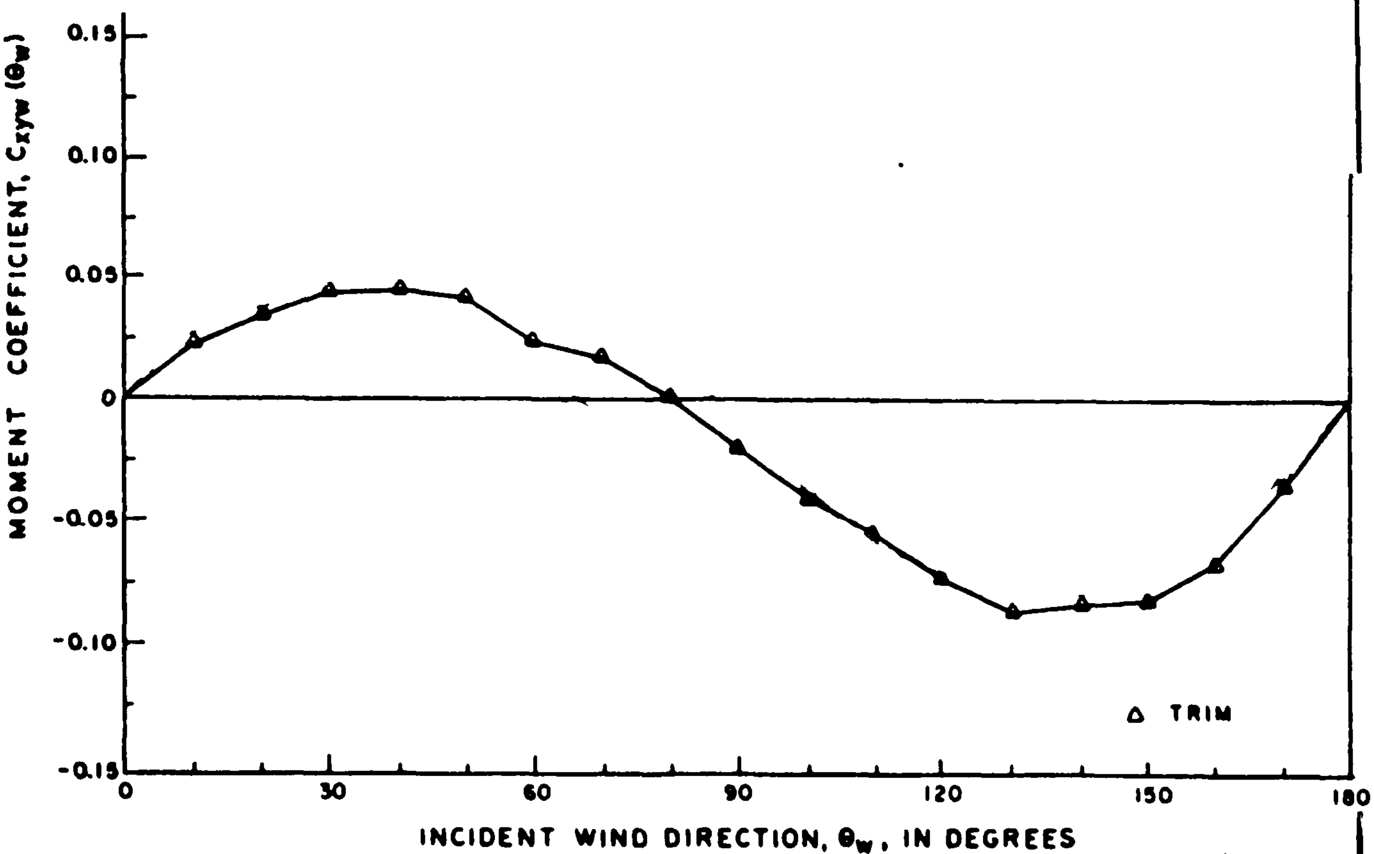

Figure 3.3

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CHESAPEAKE DIVISION **Naval Facilities Engineering Command NDW** **DISCIPLINE**	**PROJECT:** ____ **Station:** ____ **E S R:** ____ **Contract:** ____
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$$M_{xyw} = \tfrac{1}{2}(0.00237)\,V_w^2\,5210\,(405)\;C_{xyw}(\theta_w)$$

$$= \underline{\underline{2500\,V_w^2\,C_{xyw}(\theta_w)}}$$

b. Current Load.

(1) Lateral Current Load. Lateral current load is determined from the following equation:

$$F_{yc} = \frac{1}{2}\rho_w V_c^2 L_{wL} T C_{yc} \sin\theta_c$$

WHERE: F_{yc} = lateral current load, in pounds

ρ_w = mass density of water = 2 slugs per cubic foot for sea water

V_c = current velocity, in feet per second = 3.5 ft/sec

L_{wL} = vessel waterline length, in feet = 405 ft.

T = vessel draft, in feet = 8 ft

C_{yc} = lateral current-force drag coefficient

θ_c = current angle = var[illegible]

The lateral current-force drag coefficient is given by:

$$C_{yc} = C_{yc}\big|_{\infty} + \left(C_{yc}\big|_1 - C_{yc}\big|_{\infty}\right) e^{-k\left(\frac{wd}{T} - 1\right)}$$

WHERE: C_{yc} = lateral current-force drag coefficient

$C_{yc}|_{\infty}$ = limiting value of lateral current-force drag coefficient for large values of $\frac{wd}{T}$

$C_{yc}|_1$ = limiting value of lateral current-force drag coefficient for $\frac{wd}{T} = 1$

e = 2.7182818

k = coefficient

wd = water depth, in feet = 22 ft.

T = vessel draft, in feet = 8 ft.

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ______ Station: ______ E S R: ______ Contract: ______
Calcs made by: *[illegible signature]* date: ______ Calcs ck'd by: *WMS* date: ______	Calculations for: ______

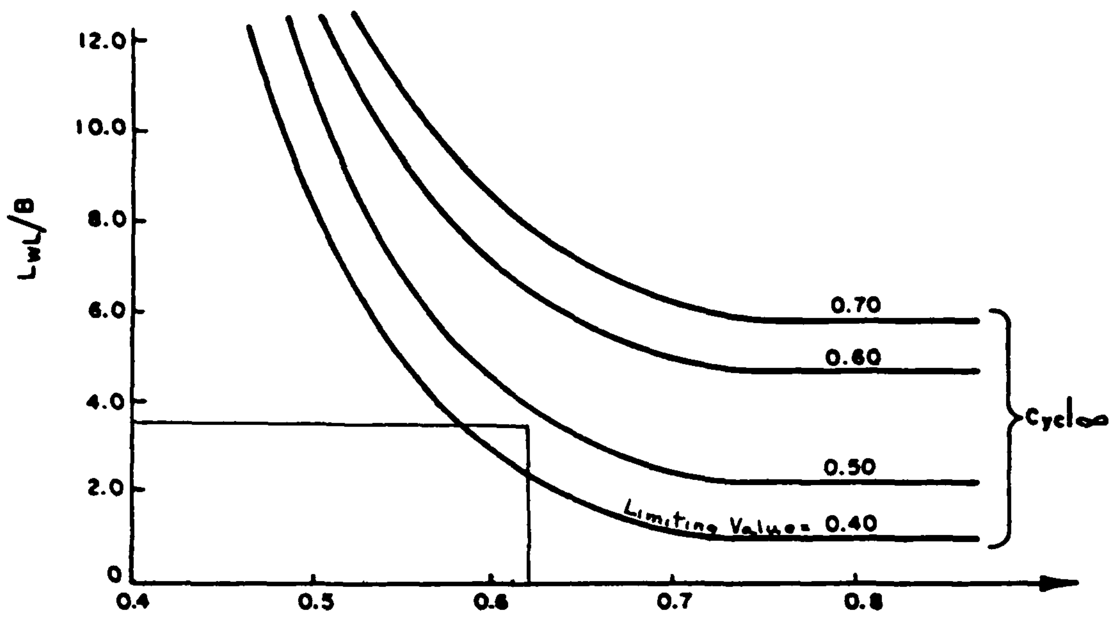

Figure 3.4

BLOCK COEFFICIENT, ϕ

The block coefficient is defined as:

$$\phi = \frac{35\ D}{L_{wL}\ B\ T}$$

WHERE: ϕ = vessel block coefficient

D = vessel displacement, in long tons: *606[illegible] tons*

L_{wL} = vessel waterline length, in feet *[illegible]05 ft.*

B = vessel beam, in feet *[illegible]*

T = vessel draft, in feet: *8 ft*

$$\phi = \frac{35(6062)}{405(105)8} = 0.624$$

$$L_{wL}/B = \frac{405}{105} = 3.86$$

$$Cyc|_\infty = 0.46$$

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Calcs made by: ____ date: ____ Calcs ck'd by: ____ date: ____	Calculations for: ____

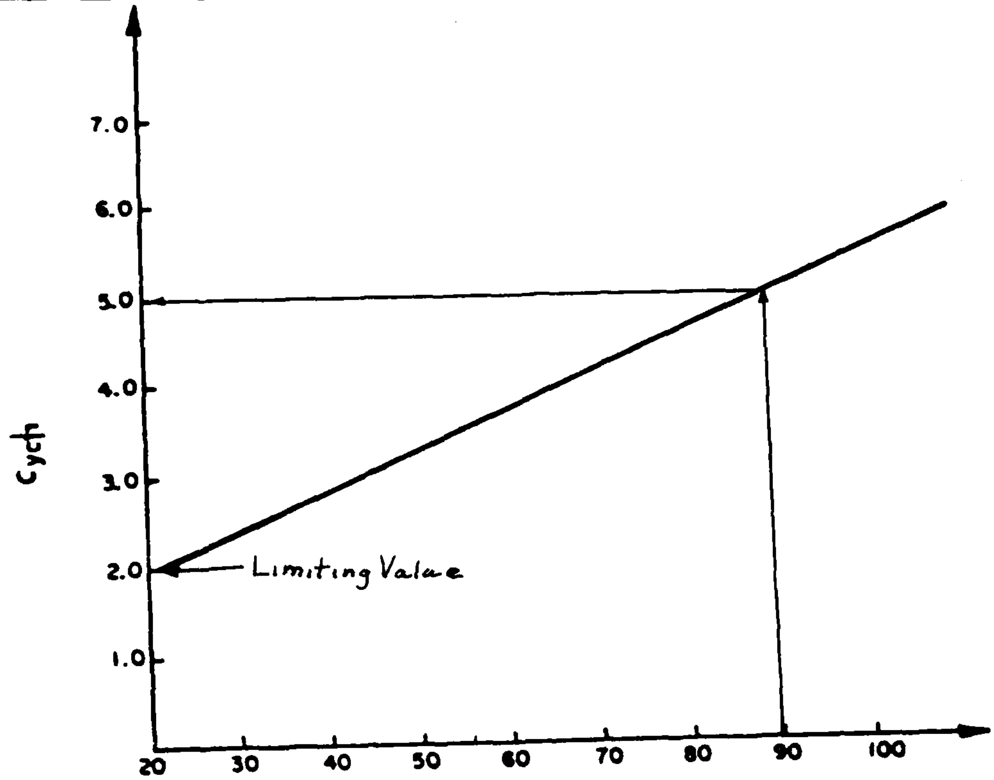

Figure 3.5

$C_p L_{wL}/\sqrt{T}$

$$C_p = \frac{\phi}{C_m}$$

WHERE: C_p = prismatic coefficient of vessel

ϕ = vessel block coefficient = 0.624

C_m = midship section coefficient

$= \frac{\text{immersed area of midship section}}{B\ T}$

B = vessel beam, in feet

T = vessel draft, in feet

$$\frac{C_p l_{wl}}{\sqrt{T}} = \frac{0.624\ (405)}{\sqrt{8}}$$

$$= 89$$

$$C_{ycl_1} = 5.$$

Because a barge has a square midship section the $C_m = 1$

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CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Station: E S R: Contract:
Calcs made by: *RR Hull* date: Calcs ck'd by: *WMS* date:	Calculations for:

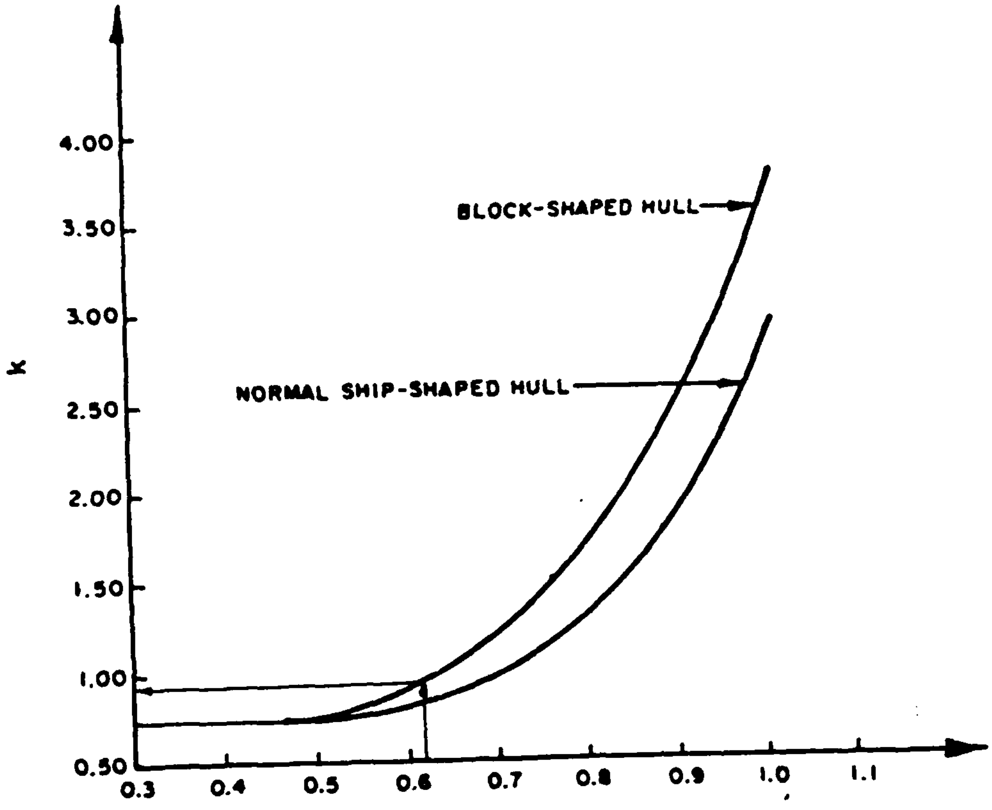

Figure 3.6 BLOCK COEFFICIENT, ϕ

$$C_{yc} = 0.46 + (5. - 0.46)\ 2.7182818^{-0.9\left(\frac{22}{8}-1\right)}$$

$$= 1.4$$

$$F_{yc} = \tfrac{1}{2}(2)\ V_c^2 (405)\ 8\ (1.4)\ \sin\theta_c$$

$$= \underline{4536\ V_c^2 \sin\theta_c}$$

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CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ______ Station: ______
Calcs made by: [illegible] date: ______ Calcs ck'd by: WAS date: ______	E S R: ______ Contract: ______ Calculations for: ______

(2) Longitudinal Current Load. Longitudinal current load procedures are taken from Cox (1982). Longitudinal current load is determined using the following equation:

$$F_{xc} = F_{x\ form} + F_{x\ friction} + F_{x\ prop}$$

WHERE: F_{xc} = total longitudinal current load

$F_{x\ form}$ = longitudinal current load due to form drag

$F_{x\ friction}$ = longitudinal current load due to skin friction drag

$F_{x\ prop}$ = longitudinal current load due to propeller drag = 0, for barges

Form drag is given by the following equation:

$$F_{x\ form} = -\frac{1}{2}\rho_w V_c^2\ B\ T\ C_{xcb} \cos\theta_c$$

WHERE: $F_{x\ form}$ = longitudinal current load due to form drag

ρ_w = mass density of water = 2 slugs per cubic foot for sea water

V_c = average current speed, in feet per second = 2.5 ft/sec.

B = vessel beam, in feet = 105 ft.

T = vessel draft, in feet = 8 ft.

C_{xcb} = longitudinal current form-drag coefficient = 0.1

θ_c = current angle

$$F_{x\ form} = -\tfrac{1}{2}(2)\ V_c^2\ 105\ (8)(.1)\cos\theta_c$$

$$= -84\ V_c^2 \cos\theta_c$$

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Friction drag is given by the folowing equation:

$$F_{x\ friction} = -\frac{1}{2}\rho_w V_c^2 S C_{xca} \cos\theta_c$$

WHERE: $F_{x\ friction}$ = longitudinal current load due to skin friction

ρ_w = mass density of water = 2 slugs per cubic foot for sea water

V_c = average current speed, in feet per second = [illegible].5 ft/sec

S = wetted surface area, in square feet
= $(1.7\ T\ L_{wL}) + (\frac{35\ D}{T})$

T = vessel draft, in feet = 8 ft

L_{wL} = waterline length of vessel, in feet = 4[illegible] ft.

D = displacement of ship, in long tons = [illegible] tons

C_{xca} = longitudinal skin-friction coefficient
= $0.075/(\log R_n - 2)^2$

R_n = Reynolds number = $V_c L_{wL} \cos\theta_c / \nu$

ν = kinematic viscosity of water (1.4×10^{-5} square feet per second)

θ_c = current angle

The formula above for wet surface area will not be used for the barge group. The actual wet surface area of the combined barges, 46,484 ft.², will be used.

$$F_{x\,friction} = -\frac{1}{2}(2)\, V_c^2\, 16{,}484\ \frac{0.075}{\left(\log \frac{V_c\, 405 \cos\theta_c}{1.4\times10^{-5}} - 2\right)^2} \cos\theta_c$$

$$= -V_c^2\ 3486.\ /\left(\log V_c\ 2.893\times10^{7} \cos\theta_c - 2\right)^2 \cos\theta_c$$

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$$F_{xc} = -V_c^2 \cos\theta_c \left(34 + \frac{2486}{(\log V_c\, 2.893 \times 10^7 \cos\theta_c - 2)^2}\right)$$

(3) <u>Current Yaw Moment.</u> Procedures for determining current yaw moment are taken from Altmann (1971). Current yaw moment is determined using the following equation:

$$M_{xyc} = F_{yc} \left(\frac{e_c}{L_{wL}}\right) L_{wL}$$

WHERE: M_{xyc} = current yaw moment, in foot-pounds

F_{yc} = lateral current load, in pounds $= 4536\, V_c^2 \sin\theta_c$

$\left(\frac{e_c}{L_{wL}}\right)$ = ratio of eccentricity of lateral current load measured along the longitudinal axis of the vessel from amidships to vessel waterline length

e_c = eccentricity of F_{yc}

L_{wL} = vessel waterline length, in feet $= 405$ ft

The value of $\left(\frac{e_c}{l_{wl}}\right)$ is derived from the graph on the following page. The vessel curve that will be used is the small auxiliary floating dry dock (AFDL). This curve is used over the other curves because the AFDL has the same underwater hull shape as barges.

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Calcs made by: date: Calcs ck'd by: date:	Calculations for:

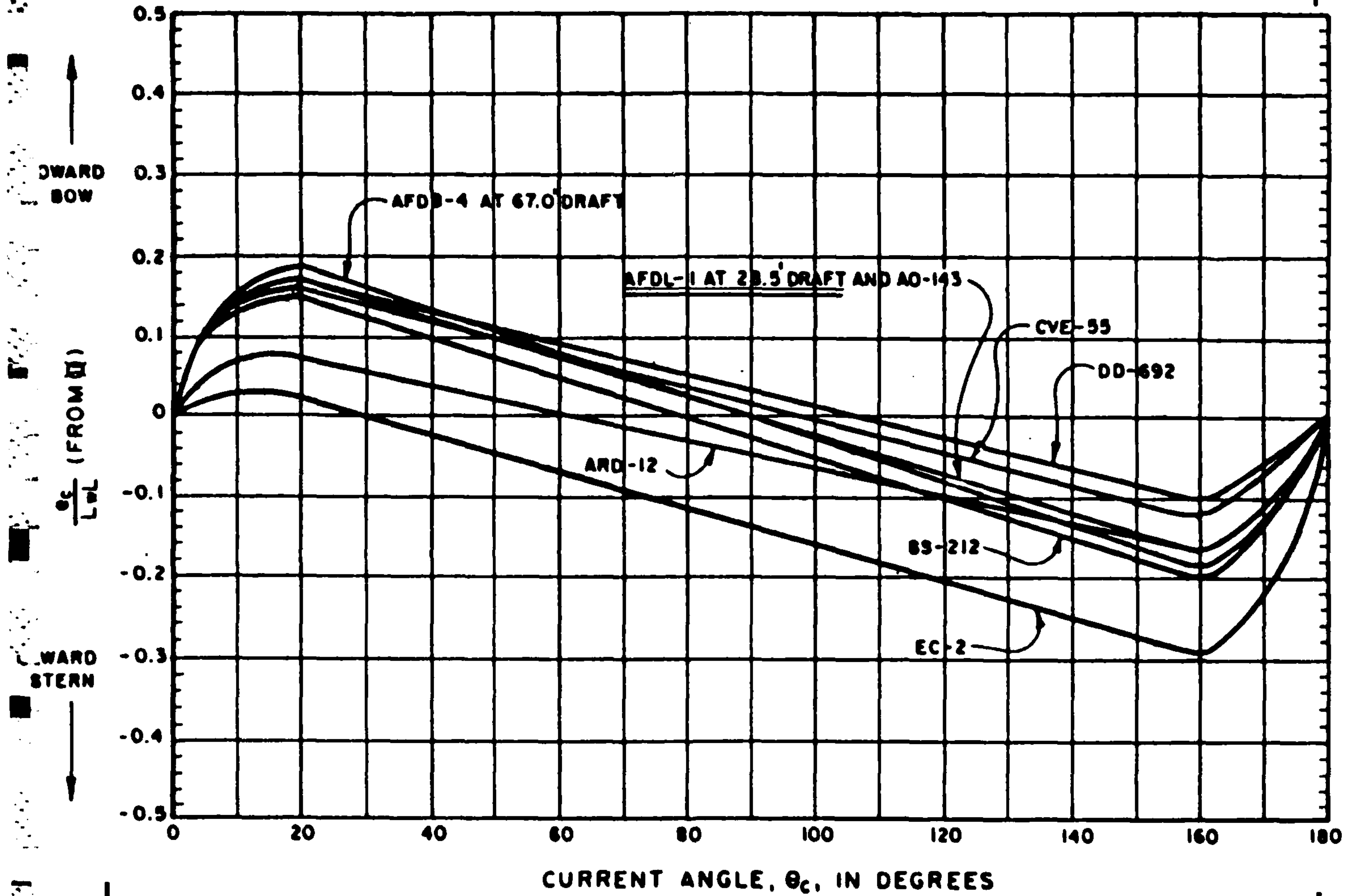

Figure 3.7

$$M_{xyc} = 4536 V_c^2 \sin\theta_c \left(\frac{e_c}{L_{wl}}\right) 405$$

$$= 1.837 \times 10^6 V_c^2 \sin\theta_c \left(\frac{e_c}{L_{wl}}\right)$$

These are all the formulas used to calculate the environmental loads on the barge.

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DISCIPLINE	E S R: Contract:
Calcs made by: [signature] date:	Calculations for:
Calcs ck'd by: NMS date:	

Environmental Static loads on the YTB

The same method used on the barges in the previous section will be used for the YTB. Therefore the details for this YTB calculation will be briefer.

YTB - Length 105'
Beam 28'
Draft 13'
Displacement 320 tons
Area Side 1790 ft²
Front 560 ft²

Wind loads

$$F_{yw} = \tfrac{1}{2} \rho_a V_w^2 A_y C_{yw} f_{yw}(\theta_w)$$

$$\frac{V_H}{V_R} = \left(\frac{3}{33.33}\right)^{1/7} = 0.709$$

$$\frac{V_S}{V_R} = \left(\frac{16}{33.33}\right)^{1/7} = 0.900$$

$$C_{yw} = .92\left[(0.90)^2(1160) + (0.709)^2(630)\right]/1790 = 0.6457$$

$$F_{yw} = \tfrac{1}{2}(0.00237)V_w^2(1790)(0.6457)\left(\frac{\sin\theta_w - 0.05\sin 5\theta_w}{0.95}\right)$$

$$= 1.370\, V_w^2\left(\frac{\sin\theta_w - 0.05\sin 5\theta_w}{0.95}\right)$$

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Calcs made by: ____ date: ____ Calcs ck'd by: NMS date: ____	Calculations for: ____

$F_{xw} = \frac{1}{2} \rho_a V_w^2 A_x C_{xw} f_{xw}(\theta_w)$

$C_{xw} = .7$

For ships with distinct superstructures such as YTB the longitudinal shape function is given below:

$f_{xw}(\theta_w) = -\cos\phi$

$\theta_{wz} = 80°$ if the superstructure is forward of midships

$\phi = \left(\frac{90}{\theta_{wz}}\right)\theta_w$ for $\theta_w < \theta_{wz}$

$= \frac{90}{80}\theta_w$ for $\theta_w < 80°$

$\phi = \left(\frac{90}{180° - \theta_{wz}}\right)(\theta_w - \theta_{wz}) + 90°$ for $\theta_w > \theta_{wz}$

$= \left(\frac{90}{180-80}\right)(\theta_w - 80) + 90°$ for $\theta_w > 80°$

$= .9(\theta_w - 80°) + 90°$

$F_{xw} = \frac{1}{2}(.00237) V_w^2 (560)(.7)(-\cos\phi)$

$= \underline{0.1645\ V_w^2 (-\cos\phi)}$

The moments due to the YTB on the mooring group are small therefore they will not be considered when summing the moments to find the zero moment crossing.

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$$F_{yc} = \tfrac{1}{2} \rho_w V_c^2 L_{wl} T C_{yc} \sin\theta_c$$

$$C_{yc} = C_{yc}|_\infty + (C_{yc}|_1 - C_{yc}|_\infty)e^{-k\left(\frac{wd}{T} - 1\right)}$$

$$\frac{wd}{T} = \frac{22}{13} = 1.7$$

$$\phi = \frac{35D}{L_{wl} BT} = \frac{35(320)}{105(28)13} = .29$$

$$\frac{L_{wl}}{B} = \frac{105}{28} = 3.75$$

Use limiting value for $C_{yc\,\infty} = 0.4$

$$C_p = \frac{\phi}{C_m} = \frac{.29}{.85} = .34$$

$C_m = 0.85$ from at tug shape

$$C_p L_{wl}/\sqrt{T} = .34(105)/\sqrt{13} = 9.9$$

Use limiting value for $C_{yc}|_1 = 2.0$

$K = .75$

$$C_{yc} = 0.4 + (2 - 0.4)\,2.7182818^{-.75(1.7-1)}$$

$$= 1.346$$

$$F_{yc} = \tfrac{1}{2}(2) V_c^2 (105)(13)(1.346) \sin\theta_c$$
$$= \underline{\underline{1837\, V_c^2 \sin\theta_c}}$$

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Calcs ck'd by: [illegible] date:	

$$F_{xc} = F_{x\,form} + F_{x\,friction} + F_{x\,prop}$$

$$F_{x\,form} = -\tfrac{1}{2}\rho_w V_c^2 BT C_{x\,cb} \cos\theta_c$$

$$= -\tfrac{1}{2}(2)V_c^2(28)(13)(.1)\cos\theta_c$$

$$= -36.4 V_c^2 \cos\theta_c$$

$$F_{x\,friction} = \tfrac{1}{2}\rho_w V_c^2 S\, C_{xca} \cos\theta_c$$

$$S = 1.7\,T\,L_{wl} + \frac{35D}{T}$$

$$= 1.7(13)105 + \frac{35(320)}{13} = 3182$$

$$C_{xca} = \frac{0.075}{\left(\log \frac{V_c L_{wl}\cos\theta_c}{1.4\times10^{-5}} - 2\right)^2}$$

$$F_{x\,friction} = \tfrac{1}{2}(2)V_c^2(3182)\frac{0.075}{\left(\log \frac{V_c L_{wl}\cos\theta_c}{1.4\times10^{-5}} - 2\right)^2}\cos\theta_c$$

$$= -\frac{238.7 V_c^2 \cos\theta_c}{(\log V_c\, 7.5\times10^6 \cos\theta_c - 2)^2}$$

Propeller drag is the form drag of the vessel's propeller with a locked shaft. Propeller drag is given by the following equation:

$$F_{x\,prop} = -\frac{1}{2}\rho_w V_c^2 A_p C_{prop} \cos\theta_c$$

WHERE: $F_{x\,prop}$ = longitudinal current load due to propeller drag

ρ_w = mass density of water = 2 slugs per cubic foot for sea water

V_c = average current speed, in feet per second

A_p = propeller expanded (or developed) blade area, in square feet

C_{prop} = propeller-drag coefficient (assumed to be 1)

θ_c = current angle

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A_p is given by:

$$A_p = \frac{A_{Tpp}}{1.067 - 0.229\ p/d} = \frac{A_{Tpp}}{0.838}$$

WHERE: A_p = propeller expanded (or developed) blade area, in square feet

A_{Tpp} = total projected propeller area, in square feet

p/d = propeller pitch to diameter ratio (assumed to be 1)

$$A_{Tpp} = \frac{L_{wL}\ B}{A_R}$$

WHERE: A_{Tpp} = total projected propeller area, in square feet

L_{wL} = waterline length of vessel, in feet

B = vessel beam, in feet

A_R = area ratio, found in Table 1

TABLE 1

A_R for Propeller Drag

Vessel Type	Area Ratio, A_R
Destroyer	100
Cruiser	160
Carrier	125
Cargo	240
Tanker	270
Submarine	125

YTB has a very small A_R and a YTM has $A_p = 27\ ft^2$ so a YTB's A_p will be larger

Use $A_R = 75$ for YTB

$$A_{Tpp} = \frac{105\,(28)}{75} = 39.2\ ft^2$$

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$A_p = \frac{372}{.???} = 46.8\ ft^2$

$F_{xprop} = -\frac{1}{2}(2)V_c^2(46.8)(1)\cos\theta_c$

$= -46.8\,V_c^2\cos\theta_c$

$F_{xc} = -V_c^2\cos\theta_c\left(36.4 + \frac{238.7}{(\log V_c(7.5\times10^5)\cos\theta_c - 2)^2} + 46.8\right)$

$= -V_c^2\cos\theta_c\left[83.2 + \frac{238.7}{(\log V_c(7.5\times10^5)\cos\theta_c - 2)^2}\right]$

Now all the formulas are complete for the vessels moored at Mooring A. Now an iterative process begins so that the mooring group position can be found when wind and current are acting on it.

The environment condition that will be tried is the wind coming out of the North at 122 ft/sec and the river flooding at 2.5 ft/sec. The current direction is from the NNE or 22.5°

Using the flow diagram on page 2

1st Try

$\theta_{c1} = \theta_{wc}/2 = 22.5° - 0°/2 = 22.5/2 = 11.25$

$\theta_{w1} = \theta_{c1} - \theta_{wc} = 11.25° - 22.5° = -11.25°$

calculate F_{yw} for $\theta_w = \theta_{w1} = -11.25°$

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CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ____ Station: ____ E S R: ____ Contract: ____ Calculations for: ____
Calcs made by: [illegible] date: ____ Calcs ck'd by: WMS date: ____	

$F_{yw\,barge} = 4.338\,V_w^2\left(\sin\frac{\theta_w - 0.05\sin 5\theta_w}{0.95}\right)$
$= -10{,}434$ lbs

$F_{yw\,YTB} = 1.37\,V_w^2\left(\sin\frac{\theta_w - 0.05\sin 5\theta_w}{0.95}\right)$
$= -3295$ lbs

$F_{yw\,Tot} = -13729$ lbs

F_{yc} for $\theta_c = 11.25$

$F_{yc\,barge} = 4536 V_c^2 \sin\theta_c$
$= 5531$ lbs

$F_{yc\,YTB} = 1837 V_c^2 \sin\theta_c$
$= 2340$ lbs

$F_{yc\,Tot} = 7571$ lbs

$F_{yT} = F_{yw} + F_{yc} = -5858$ lbs

M_{xyw} for $\theta_w = -11.25°$, $C_{xyw} = -0.02$
$M_{xyw} = 2500\,V_w^2\,C_{xyw}(\theta_w)$
$-744{,}200$ ft-lbs

M_{xyc} for $\theta_c = 11.25°$, $\left(\frac{e_c}{L_{wl}}\right) = 0.14$
$M_{xyc} = 1837\times10^{6}\,V_c^2 \sin\theta_c\,(0.14)$
$= 313{,}600$ Ft-lbs

$M_{xyT} = M_{xyw} + M_{xyc} = -130600$ ft lbs

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ______ Station: ______ E S R: ______ Contract: ______
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$\Sigma M_1 = M_{xyT} + F_{yT}(1/2)L_{wl} =$
$= -430600 - (-5858)(.5)(105)$
$= 755,491 \text{ ft-lbs}$

2nd Try / $\theta_{c2} = 0,\ \theta_{w2} = \theta_{c2} - \theta_{wc} = 0 - 22.5° = -22.5$

$F_{yw\,barge} = 4.338 V_w^2 \left(\sin\theta_w - \frac{0.05}{0.95}\sin 5\theta_w\right)$
$= -22,870 \text{ lbs}$

$F_{yw\,YTB} = 1.37 V_w^2 \left(\sin\theta_w - \frac{0.05}{0.95}\sin 5\theta_w\right)$
$= -7,220 \text{ lbs}$

$F_{yw\,TOT} = -30,090 \text{ lbs}$

F_{yc} for $\theta_{c2} = 0°,\ = 0$

$F_{yT} = -30,090 \text{ lbs}$

M_{xyw} for $\theta_w = -22.5$, $C_{xyw} = -0.035$
$M_{xyw} = 2500 V_w^2\, C_{xyw}(\theta_w)$
$= -1,302,350 \text{ ft-lbs}$

M_{xyc} for $\theta_c = 0,\ = 0$

$M_{xyT} = -1,302,350 \text{ ft-lbs}$

$\Sigma M_2 = M_{xyT} - F_{yT}(1/2)L_{wl}$
$= -1,302,350 - (-30090)(1/2)(105)$
$= 4,790,900 \text{ ft-lbs}$

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ΣM_1 to ΣM_2 did not change signs

$\therefore \theta_{c2} = \theta_{cw} = 22.5°$

$\theta_{w2} = \theta_{c2} - \theta_{wc} = 22.5° - 22.5° = 0°$

$F_{yw} = 0$

$F_{yc\ barge} = 4536 V_c^2 \sin \theta_c$

$= 10,850$ lbs

$F_{yc\ YTB} = 1837 V_c^2 \sin \theta_c$

$= 4390$ lbs

$F_{yc\ TOT} = 15240$ lbs

M_{xyw} for $\theta_{w2} = 0°$, 0

M_{xyc} for $\theta_{c2} = 22.5°, \left(\frac{e_c}{l_1}\right) = 0.16$

$M_{xyc} = 1.837 \times 10^6 V_c^2 \sin \theta_c (0.16)$

$= 702,990$ ft-lbs

$M_{xyT} = 702,990$ ft-lbs

$\Sigma M_2 = M_{xyT} - F_{yT} (1/2) l_{w1}$

$= 702990 - (15240).5(405)$

$= -2,383,110$ ft-lb

Third Try

$\theta_{c3} = \frac{\theta_{c1} + \theta_{c2}}{2} = \frac{11.25° + 22.5°}{2} = 16.875°$

$\theta_{w3} = \theta_{c3} - \theta_{wc} = 16.875° - 22.5° = -5.625°$

$F_{yw\ barge} = 4.338 V_w^2 \left(\frac{\sin \theta_w - 0.05 \sin 5\theta_w}{0.95}\right)$

$= -5060$ lbs

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$F_{YwYTB} = 1.37 V_w^2 \left(\frac{\sin\theta_w - 0.05 \sin 5\theta_w}{0.95}\right)$
$= -1600$ lbs

$F_{YwTot} = -6660$ lbs

$M_{xyw} = 2500 V_w^2 C_{xyw} \theta_w$
$= 2500 V_w^2 (-0.01)$
$= -3,721,000$ ft lbs

M_{xyc} for $\theta_c = 16.875°$, $\left(\frac{e_c}{L_{wl}}\right) = 0.158$

$M_{xyc} = 1.837 \times 10^6 V_c^2 \sin\theta_c (0.158)$
$= 526,600$

$M_{xyT} = M_{xyw} + M_{xyc} = -3,194,400$ ft·lbs

$F_{yc\,barge} = 4536 V_c^2 \sin\theta_c$
$= 8230$ lbs

$F_{ycYTB} = 1837 V_c^2 \sin\theta_c$
$= 3330$ lbs

$F_{yT} = -3330$ lbs

$\Sigma M_3 = M_{xyT} - F_{yT} (1/2) L_{wl}$
$-3,194,400 - (-3330 (.5) 405)$
$= -2,520,000$ ft-lb

4th Try

ΣM_3 and ΣM_2 did not change signs $\therefore$ $\theta_{c4} = \frac{\theta_{c1} + \theta_{c3}}{2} = \frac{11.25 + 16.875}{2} = 14.0625°$

$\theta_{w4} = \theta_{c4} - \theta_{wc} = 14.0625° - 22.5° = -8.4375°$

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$F_{YwTOT} = F_{Ywbarge} + F_{YwYTB} = 5.705\, V_w^2 \left(\sin\theta_w \frac{0.05 \sin 5\theta_w}{0.75} \right)$
$= -10,120$ lbs

$F_{YcTOT} = F_{Ycbarge} + F_{YcYTB} = 6373\, V_c^2 \sin\theta_c$
$= 9680$ lb

$F_{YT} = -440$ lbs

M_{xyw} for $\theta_{w4} = -8.375°$, $C_{xyw} = -0.02$
$M_{xyw} = -744,200$ ft-lbs

M_{xyc} for $\theta_{c4} = 14.0°$, $\frac{a_c}{l_{wl}}$ 0.153
$M_{xyc} = 426800$ ft-lbs

$M_{xyT} = -317,400$ ft-lbs

$\Sigma M_4 = M_{xyT} - F_{YT}(1/2)(lwl)$
$= -317400 - (-440(.5)405)$
$= -228,300$ ft-lbs

The graph on the following page is a plot of the ΣM with reference to θ_c. The graphical solution shows $\theta_c \doteq 13.5°$

$\therefore\ \theta_w = \theta_c - \theta_{wc} = 13.5 - 22.5 = -9°$

The loads will now be calculated using $\theta_w = -9°$ and $\theta_c = 13.5°$

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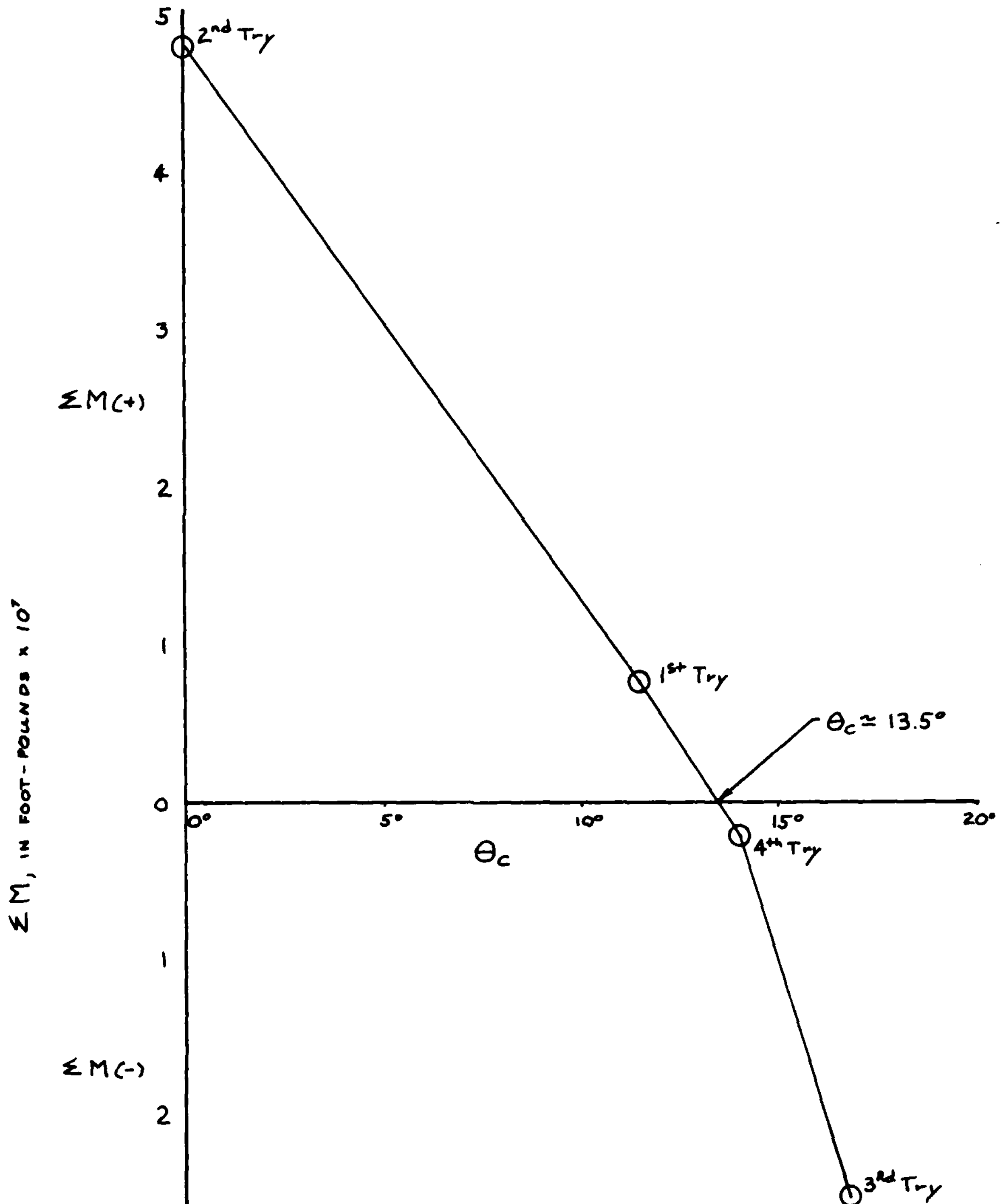

Figure 3.8

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CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW	**PROJECT:**
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Calcs made by: [illegible] **date:**	**Calculations for:**
Calcs ck'd by: [illegible] **date:**	

$F_{YIW\ldots} = 4.338(122)^2 \frac{\sin 9^\circ - 0.05 \sin \ldots 9^\circ}{0.75}$
$= -3230$ lbs

$F_{YIWYTB} = 1.37(122)^2 \frac{\sin \ldots - 0.05 \sin 5(-9^\circ)}{0.75}$
$= -2600$ lbs

$F_{YIWTot} = -10,830$ lbs

$F_{XIWbarge} = 1.526(122)^2\left(-\left(\frac{\sin 81 - 0.1 \sin 5(81^\circ)}{0.9}\right)\right)$ $\quad \gamma = -9^\circ + 90^\circ$
$= -23,140$ lbs

$F_{XIWYTB} = 0.4645(122)^2 - \cos\left(\frac{90}{80} \times 9^\circ\right)$
-6800 lbs

$F_{XWTotal} = 29,940$ lbs

$F_{YCbarge} = 4536(2.5)^2 \sin 13.5^\circ$
$= 6600$ lbs

$F_{YCYTB} = 1837(2.5)^2 \sin 13.5^\circ$
$= 2680$ lbs

$F_{YCTotal} = 9280$ lbs

$F_{XCbarge} = -2.5^2 \cos 13.5^\circ \left(34 + \frac{3786}{(\log(2.5)\, 2.893 \times 10^7 \cos 13.5^\circ - 2)^2}\right)$
$= -1130$ lbs

$F_{XCYTB} = -2.5^2 \cos 13.5\left[832 + \frac{2387}{\log(2.5)(7.5 \times 10^6) \cos 13.5^\circ - 2)^2}\right]$
$= -550$ lbs

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$F_{x\ total} = 1633$ lbs

$F_{YT} = -10,830 + 9280 = -1550$ lbs

$F_{XT} = 29940 + 1,680 = 31,620$ lbs

hawser load $= \sqrt{F_{XT}^2 + F_{YT}^2}$

$= \sqrt{1550^2 + 31620^2}$

$= \boxed{31,660 \text{ lbs}}$

The hawser load calculation takes about 4 hrs to do with someone that is experienced and this is only for one wind direction. There are 8 wind directions to do. The value of the answer is also limited in that it does not give a feel for the loads as the vessels move, hence a static answer. We in Ches Div developed some software to do this lengthy calculation on a computer. This hand calculation was done to validate the software. On the pages that follow this software and the output from it will be explained.

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Software for solution of hawser loads of a free-swing mooring.

The software uses the same equations as shown in the previous hand calculation. The output is in the form of a graph which shows the moment and the hawser loads as the vessel is rotated 360°.

A single graph is for a given wind and current, velocity, and direction. A computer run for a single graph takes about 15 minutes.

An example of the output for the problem which was done by hand is shown on the following page. The remainder of the graph outputs for the other loading conditions can be found in the appendix A.

This output is shown just to validate the software. The zero moment occurs when the vessel has a heading of 8° or $\Theta_w = -8°$ and $\Theta_c = 14.5°$. The corresponding hawser load is 31.7 kips. There is some rounding in the angle and the load but the answers show that the software is within less than 5% of the angle and within less than 0.1% of the hawser load thus validating the software.

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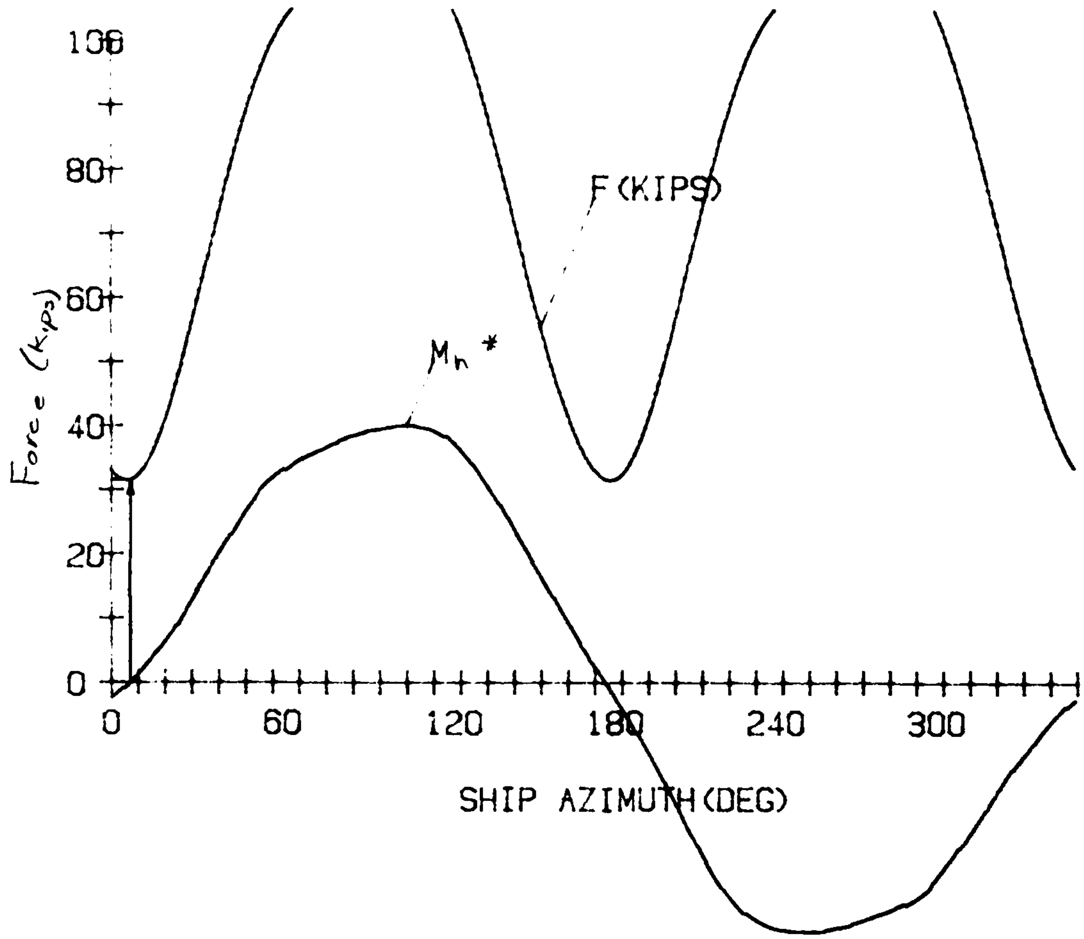


```
WIND SPEED(FPS),A(DEG)=122.0  0.0 CURRENT SPEED(FPS),A(DEG)=   2.5  22.5

 8  16.E+004 -7.E+005 42.E+004 -9.E+003 71.E+002 -3.E+004 -1.E+003  31.7
184 -1.E+004 -3.E+005 -5.E+005 47.E+002 -9.E+003 30.E+003 16.E+002  31.6
```

$\Sigma M = 0$ @ 8°

Hawser Load - 31.7 kips

Figure 3.9

* M_n is a normalized dimensionless moment which is used only to indicate zero moment.

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A quasi-dynamic solution will be performed using the graphical solution shown previously. When a vessel is in a mooring and the wind is up, the ship swings or flags in her mooring. The figure 3.10 shows this. This deviation from the direction that the wind blows can be as much a ± 20° from the direction of the wind. This amount of flagging is a function of many things such as length of hawser, speed of wind, speed of wind, stiffness of the mooring system and others. A 20° deviation will be used for this analysis.

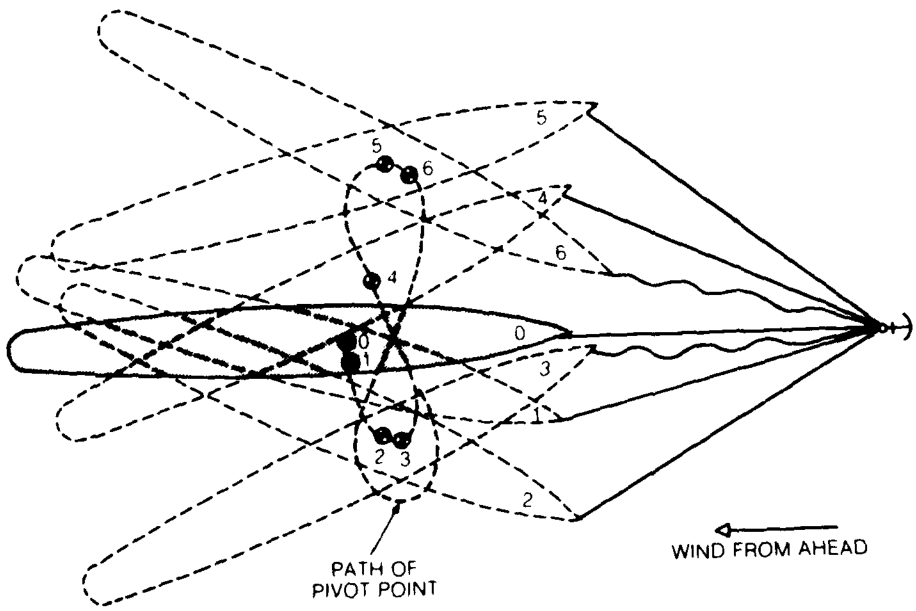

FIGURE 3.10 Manner in which a ship swings in the wind when at anchor.

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	Calculations for:

The additional loads due to the ship flagging can be derived from the graphical output of the software. Twenty degrees are added to and subtracted from the zero moment crossing. From the graph below one can see that the +20° from zero moment increased the load to 54 kips.

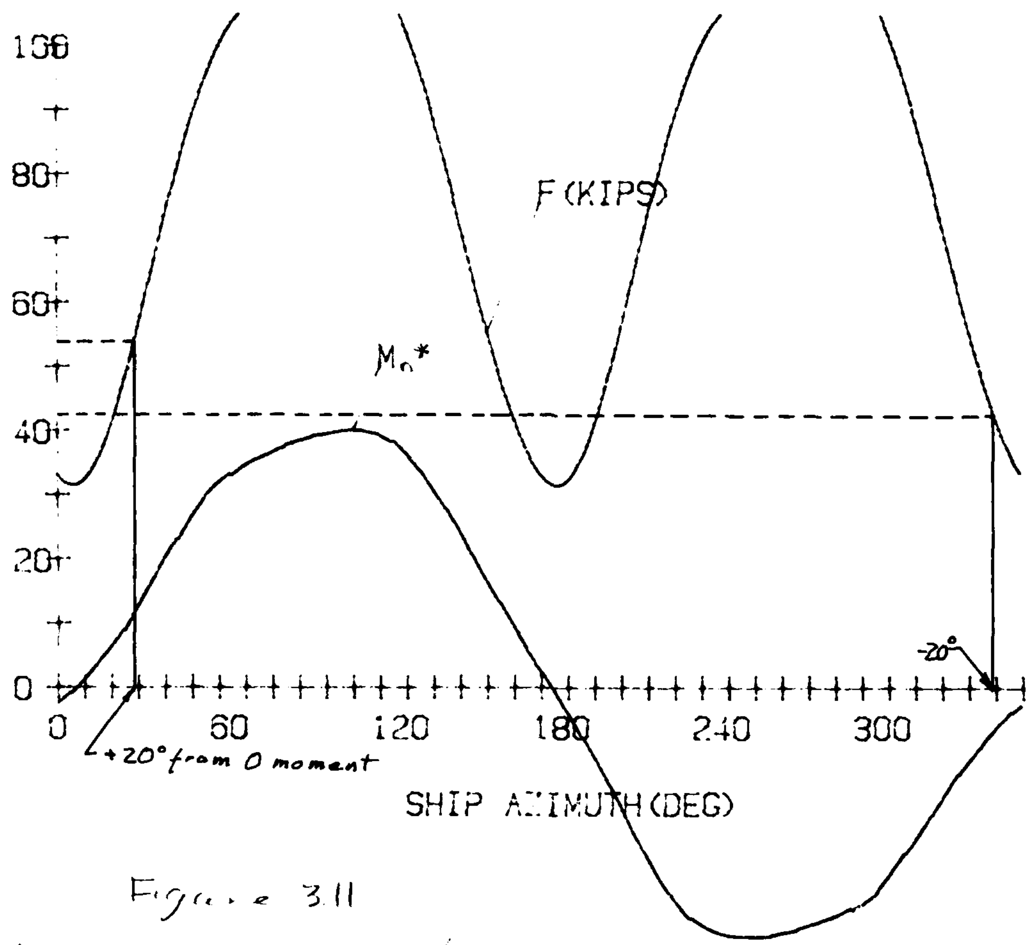

Figure 3.11

* M_n is a normalized dimensionless moment which is used only to indicate zero moment.

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All 8 wind directions were run with either flooding or ebbing current. The static solution for zero moment crossings was obtained and then ±20° added to that zero moment crossing, thus obtaining a quasi-dynamic solution from the flagging. From this a polar plot was made of the hawser loads of both the static and quasi-dynamic solutions, which is shown below.

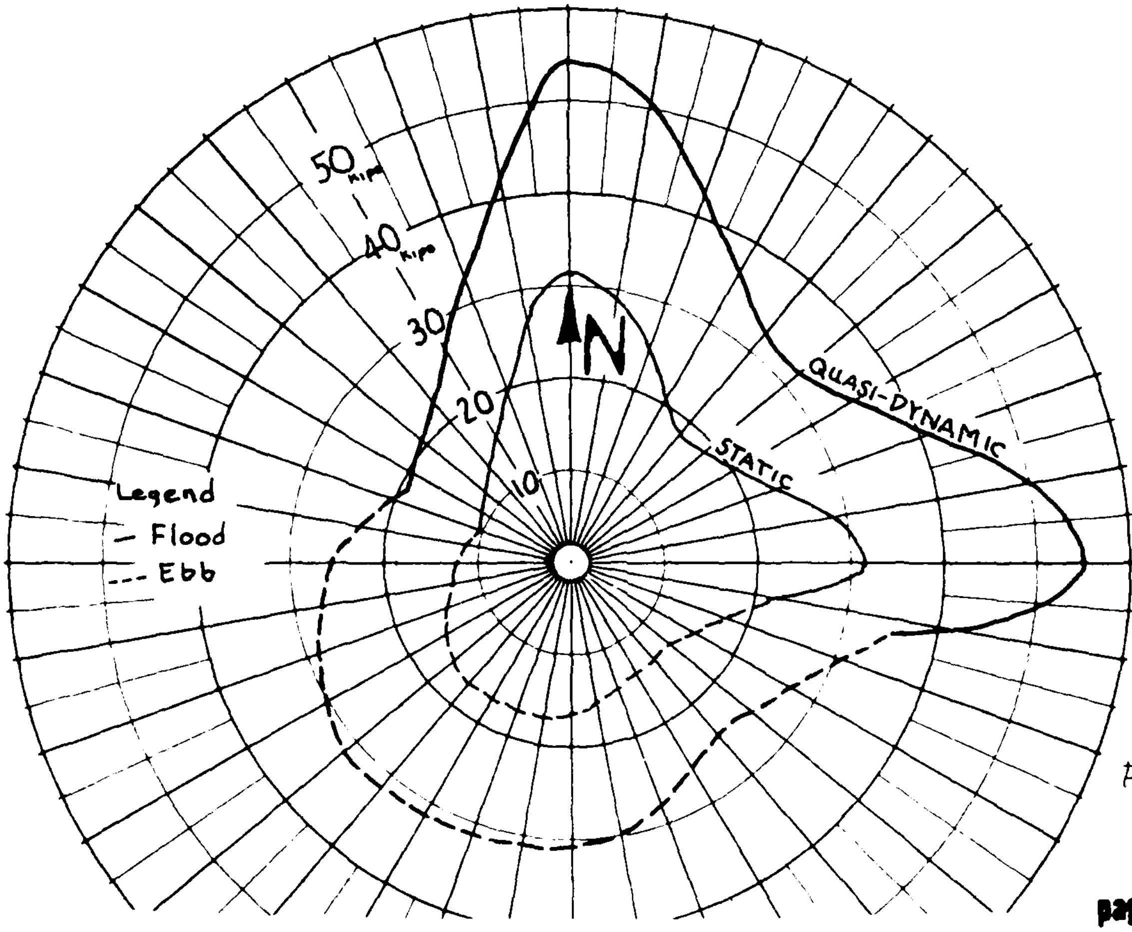

Figure 3.12

CHESAPEAKE DIVISION	PROJECT:
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The last figure showed a strong directional loading for the mooring. The highest loads were 51 kips for the North direction and 55 kips for the East direction. This directionality will have to be accounted for in the mooring orientation.

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Calcs ck'd by: MRS **date:**

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E S R: **Contract:**
Calculations for:

IV Dynamic Environmental Loading

Wave Action Dynamics

The moorings are located in a river where there is a limited fetch for which waves can be generated. Significant wave heights were predicted using COE, Coastal Engineering Research Center, Coastal Engineering Technical Note -I-6, 3/81. A figure from that report is shown below.

Note: Waves in a water depth of 25 feet with wave periods less than 3.1 secs. are considered to be deepwater waves, i.e. $d/T^2 > 2.56$.

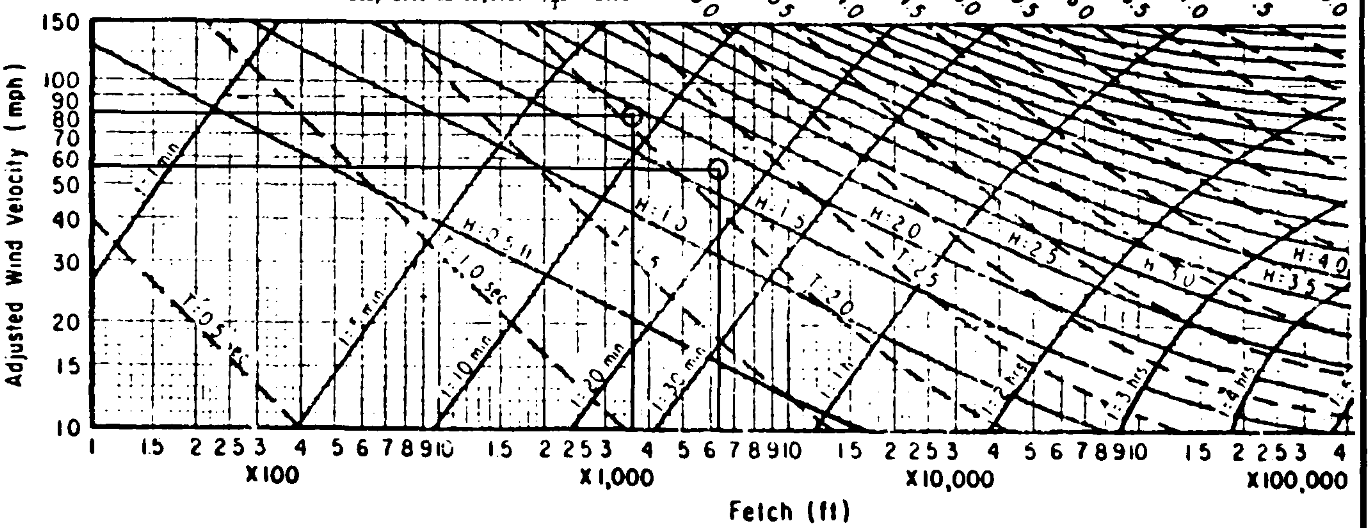

Figure 4.1 Forecasting Curves for Shallow-water Waves. Constant Depth = 25 Feet.

The results are that the North direction has 80 MPH wind but only 3600 ft of fetch generate a 1.9 ft wave, and the Southwest has 6340 ft of fetch but only 56 mph winds generate a 1.75 ft wave.

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These limited waves will not have a dynamic effect on the mooring.

Wind Action

This section is concerned with the dynamic effect that wind has on a mooring system. A one degree of freedom numerical model of mooring dynamics was created in-house by Mr. W. Seelig. This paper can be found in Appendix B. This dynamic analysis is another technique used to define the hawser loads. When compared with the other techniques, as shown on figure 4.3, the load response is reasonable.

An input to the model is a wind spectrum. This spectrum is used to create a model of the real time wind which is the forcing function on the mooring model. The spectrum used in the model was derived from the Journal of the Structural Division, Proceedings of the ASCE, June 1968 titled "Gust Response Factors" by J. Vellozzi and E. Cohen. The spectrum was also used by Exxon Research and Engineering Co. in a report titled "Guidelines for Deepwater Port Single Point Mooring Design."

A typical output can be seen in figure 4.2 on the following page. The remaining 7 graphs for the other directional loads can be seen in the Appendix C. From these graphical outputs a hawser load rose was created for the

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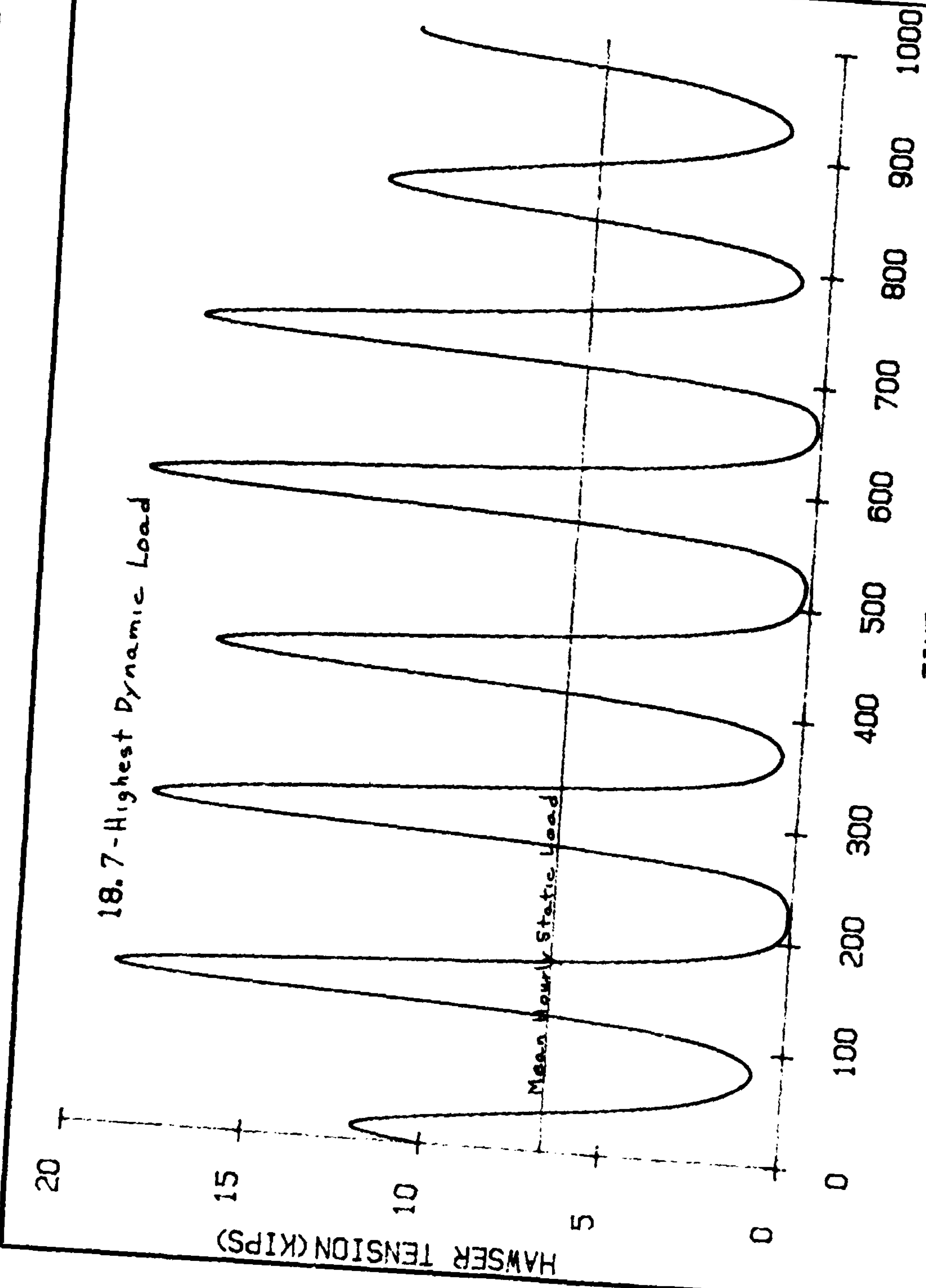

Figure 4.2 Dynamic Hawser Loads for Wind at 180° Bearing with an Ebb Tide.

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dynamic response. It was plotted on the load rose created previously and can be seen below. The dynamic load was greater than the quasi-dynamic in one case only. This was the North direction and it only increased by 1 kip over the 54 kips of the quasi-dynamic solution.

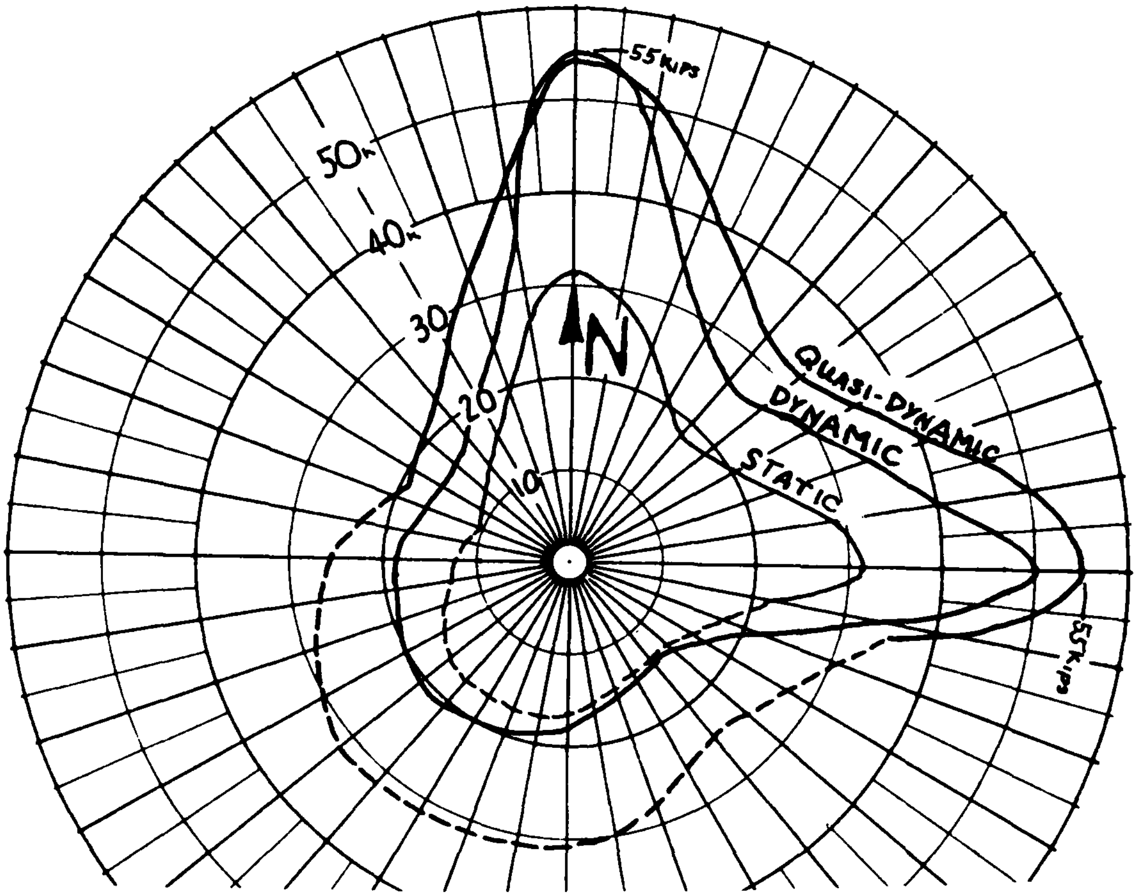

Figure 4.3

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The conclusions from the static and dynamic environmental loading of the moorings are that the maximum load will be 55kips from the North and East and 30kips from the South and West. Because these loads are relatively low, all moorings will be designed and built for a load of 55kips from any direction.

The dynamics due the movement of the mooring group is considered to be minimal because the waves are small and the barges will be rafted together with wire rope. Therefore the dynamic loading due to the articulating vessel group was not considered in this analysis.

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V Mooring System Design

.1 Anchor selection

.1.1 Geotechnical Data

There are 3 sources of geotechnical data: Army Corps of Engineers, Jacksonville Port Authority and Law Engineering.

.1.1.1 The US Army COE geotechnical information was derived from 20 ft. long vibracores taken in 1977 in the river channel. The cores were adjacent to the mooring site. All cores indicated 20 ft of black organic silt.

.1.1.2 The Jacksonville Port Authority has two sets of geotechnical data. One set is from the design effort of a fixed bridge and the other set is from the design of a new wharf. The mooring site is equal distance from both sets of data. The overview of the geotechnical is shown in figure 5.1.

5.1.1.3 Law Engineering investigated the mooring site with 3 borings. The results can be found in Appendix D.

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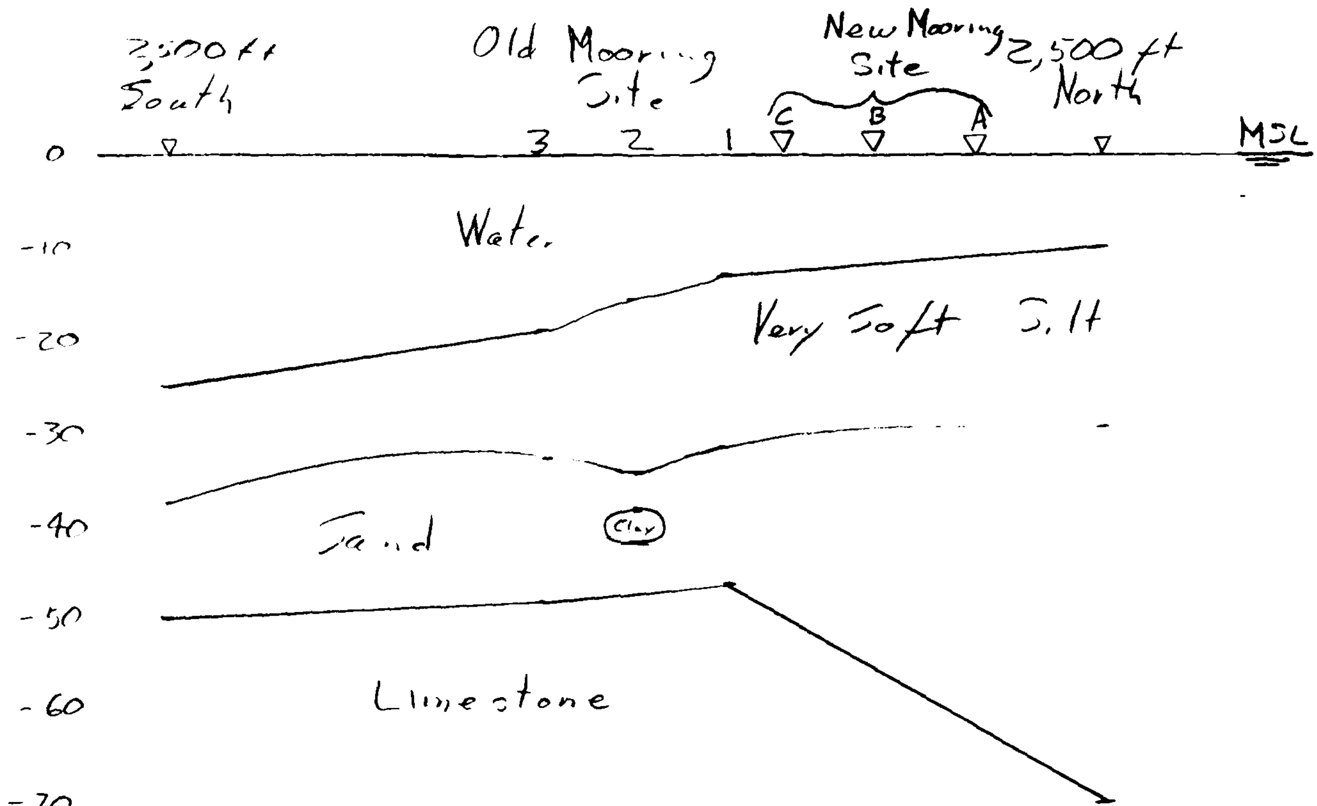
Geotechnical Overview.



Sketch —
Figure 5.1

1.1.4 Conclusions

The sketch above shows a geotechnical crossection The very soft silt at all geotechnical investigation sites did not have shear strength analysis performed on them. There was a site on the South of the island that the moorings are adjacent to that did have shear strength values.

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The soils at this site showed a very soft silt, 31 ft. thick with sand underlying this which is the same strata as at the mooring site. The shear strength in the top 16 ft increased from 220 PSF at the top to 650 PSF, 16 ft below the top. The soil shear strength increases with depth at 27 psf / ft.

According to NCEL Technical Note-N-1688 an increase in soil strength of 10 psf/ft is sufficient for holding in mud. Therefore a Navy stockless anchor with stabilizers will be used.

The next question is if there is sufficient thickness of mud to hold a stockless anchor. The NCEL Report titled "Design Guide for Drag Embedment Anchors", Technical Note N-1688, Jan. 1984 will be used to select the proper anchor.

Design load = 55 kips = H_D

Calculate the ultimate horizontal holding capacity, H_u.

$H_u = FS \times H_D$ The factor of safety, FS, for stockless anchor is 1.5

$= 1.5 \times 55$

$= 82.5$ kips

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Select an anchor size using $T_u = T_M$ from the figure below.

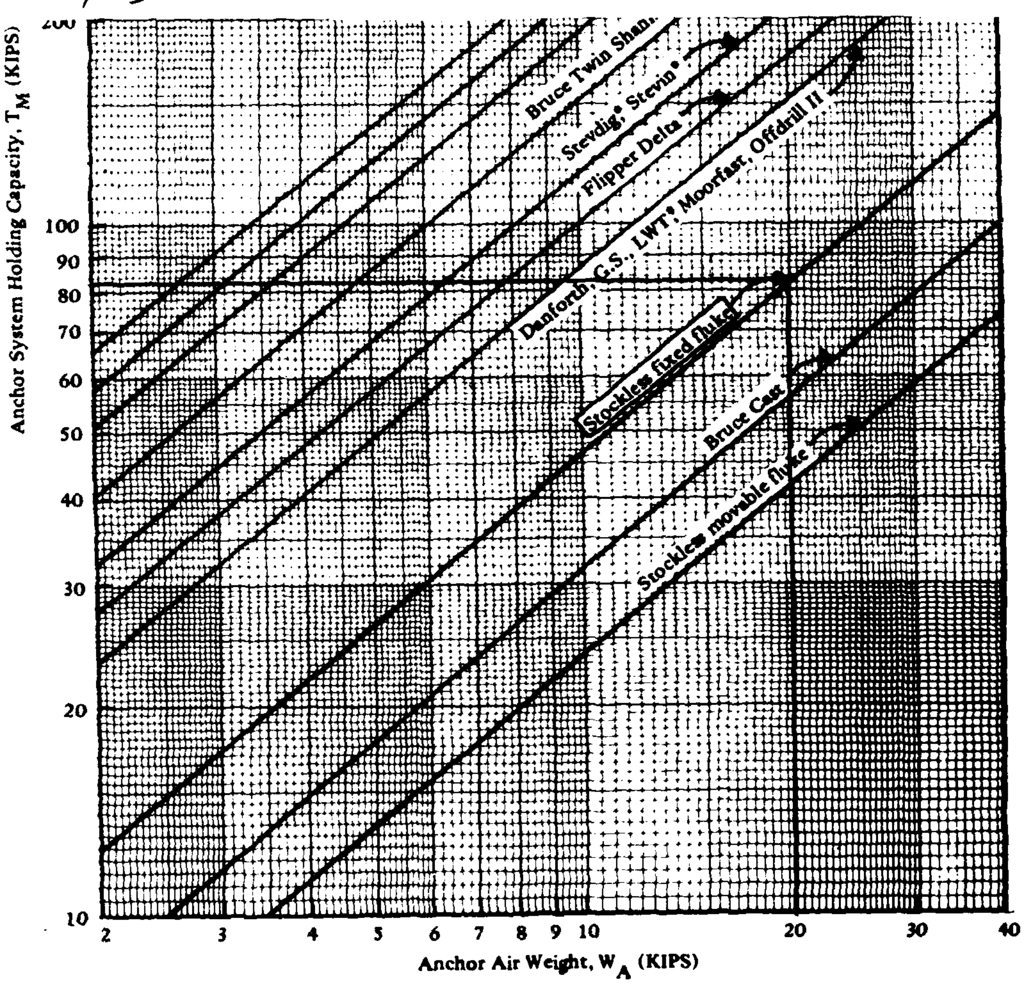

Figure 5.2 Holding capacity at mudline - mud (anchor-chain system).

The selected anchor is a 20 kip stockless with fixed flukes opened to 50°.

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Calcs ck'd by: WMS date:	

Determine if soil thickness is adequate
The normalized fluke tip penetration for a stockless in mud is 3. This multiplied by the fluke length of 6.8 ft gives a required soil thickness of 20.4 ft. The silt layer at the mooring site is only about 18 ft thick. After consulting with NCEL and using a mathematical model for predicting hold capacity, a new soil thickness was calculated to be 15 ft of 12 psf/ft soil which has an ultimate holding capacity of 91,300 lbs. Therefore the 20 kip stockless anchor is approved if the soil depth and shear strength of the anchor location meet the above criteria. Because 20K anchors are available only on the West Coast, a 25 kip stockless anchor will be used. For the 25K stockless to have a holding capacity of 55 kips, 19 ft. of silt must be present at all anchor locations. Once again the flukes will be set open at 50°.

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Chain Selection

T_u, Ultimate capacity = 1.15 x Factor of Safety, 3 x Design Load, HD

$T_u = 1.15 \times 3 \times 55k = 189.75k$

1¾ in stud link Grade 2 has a breaking strength of 249 kip and would be sufficient but because of availability 2" grade 3 stud link chain will be used.

Determine tension at vessel

$T_D = w(k+d)$

w = chain weight per ft = 31.9
$k = H_D/w = 55000/31.9 = 1724$
d = water depth = 22' + 3' tide = 25

$T_D = 55800$ lbs

$T_U = FS \times T_D$
$= 3 \times 55800$
$= 167{,}400$ lbs

T_U for 2" Grade 3 Chain is 454,000 lbs

∴ Chain is ok to use

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The chain length will be a standard class D mooring which has 2½ shots for each ground leg plus the riser chain. There will also be a 10 kip water weight sinker attached to the ground ring.

Buoy requirements with 2 ft. of freeboard.

Length of chain suspended in water is 25' which multiplied by the unit weight of 31.9 equals about 800 lbs. The existing 9.5' by 7' buoys at site will be adequate.

$$\text{Buoyancy} = \pi (4.75)^2 (5) 64 - 7700 (\text{buoy wt.})$$

$$= 15 \text{ kips}$$

Cathodic Protection

Surface area per shot
$= 0.91 \text{ ft}^2/\text{link} \times 135 \text{ links}/\text{shot} \times 50\%$ area unpainted
$= 61.4 \text{ ft}^2$

Mil spec zinc (Mil Spec A-18001) produces
$350 \frac{\text{Amp hr}}{\text{lb}}$

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$10\ ^{ma}/_{ft}$ need in sea water

What is the life for a 250 lb anode

$$Life = \frac{(250\ lb)\ 350\ \frac{Amp\cdot hr}{lb}}{(8760\ ^{hr}/_{yr})(0.01\ \frac{Amp}{ft^2})\ 61.4\ ft^2} = \underline{16\ yrs.}$$

∴ A 250 lb zinc anode with continuity wire will be used

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Conclusion Requirements:

1. Adequate silt thickness of 19 ft. has to be determined at each anchor location.
2. The ground legs will be oriented North, South, East and West.
3. At the time of installation the anchors will be proof loaded to design load of 55 kips for a period of 15 minutes.

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CHESAPEAKE DIVISION	PROJECT:
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: date:	Calculations for:
Calcs ck'd by: WMS date:	

VI Bill of Material for One mooring

Item	Description	Qty
1	25kip Stockless Anchor w/ stabilizer	4
2	Chain 2" Grade 3 1 shot	8
3	Chain 2" Grade 3 1/2 shot	5
4	10kip In water Weight Sinker	1
5	Ground Ring 2" chain size	1
6	Swivel 2"	5
7	Detachable Links 2"	13
8	Anchor Joining Link 2"	10
9	Detachable Link 2½" (for sinker)	1
10	Zinc Anodes 250 lbs	9
11	Hose Clamps	320
12	Continuity Wire 7/8" IWRC	1000'
13	Sea Cushion type fenders (4'x7.4' long)	10

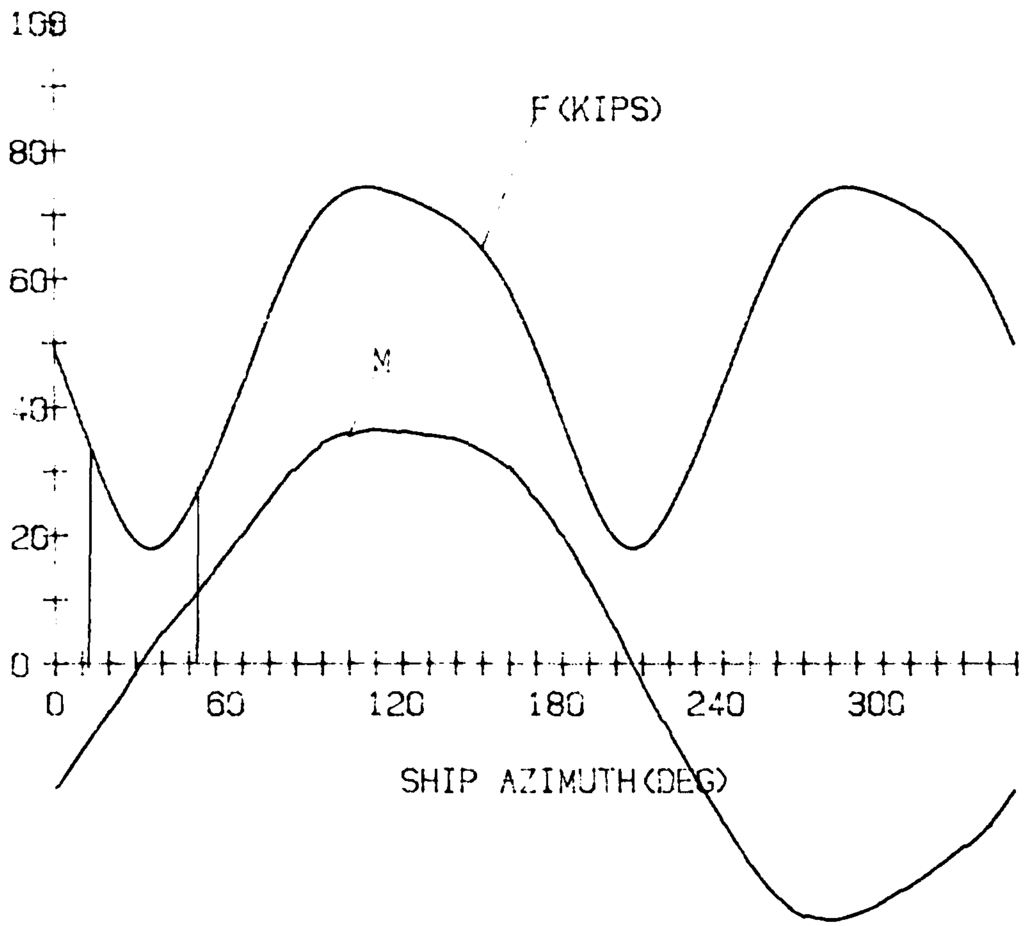
This list does not contain spare parts for mooring hardware.

GPO 886-653

CHESAPEAKE DIVISION
Naval Facilities Engineering Command NDW
DISCIPLINE

Calcs made by: ______ **date:** ______
Calcs ck'd by: ______ **date:** ______

PROJECT: ______
Station: ______
E S R: ______ **Contract:** ______
Calculations for: ______

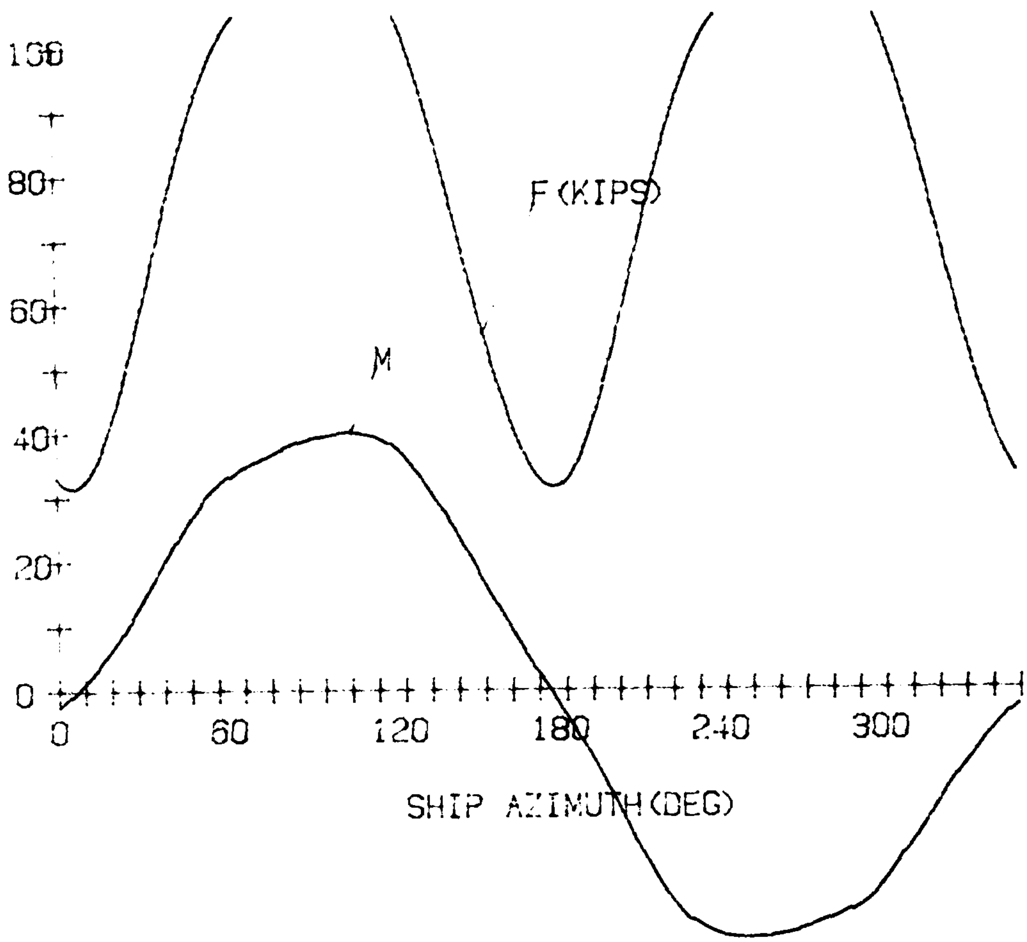


WIND SPEED(FPS),A(DEG)= 39.5 45.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

[illegible] [illegible].E+004 48.E+004 29.E+004 79.E+002 -5.E+003 -1.E+004 -1.E+003 18.1
[illegible] [illegible].E+004 54.E+004 -4.E+005 -5.E+003 66.E+002 16.E+003 17.E+002 17.8

GPO 885-653

CHESAPEAKE DIVISION **Naval Facilities Engineering Command NDW** **DISCIPLINE**	**PROJECT:** ______ **Station:** ______ **E S R:** ______ **Contract:** ______
Calcs made by: ______ **date:** ______ **Calcs ck'd by:** ______ **date:** ______	**Calculations for:** ______



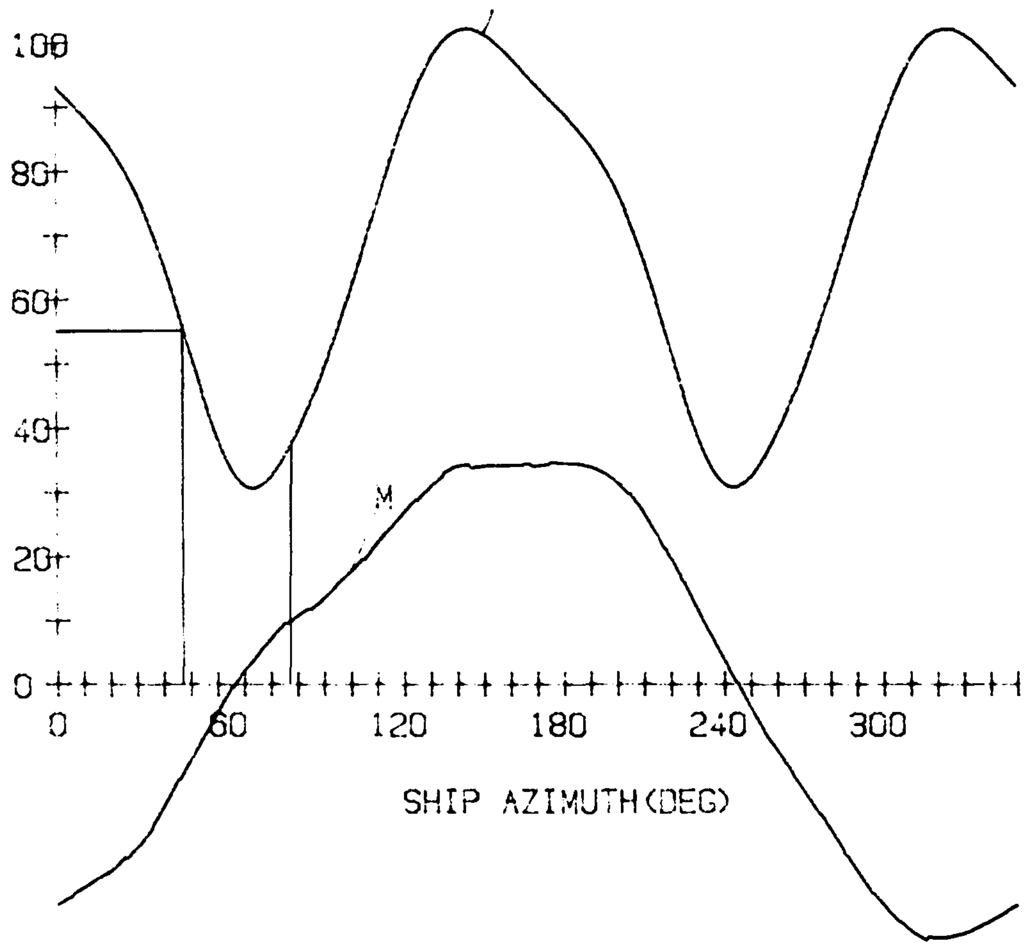
WIND SPEED(FPS),A(DEG)=[illegible] CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

[illegible] 15.E+004 -2.E+005 42.E+004 -9.E+003 71.E+002 -3.E+004 -1.E+003 31.7
184 -[illegible].E+004 -2.E+005 -[illegible].E+005 47.E+002 -[illegible].E+003 30.E+003 16.E+002 31.6

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ____ Station: ____ E S R: ____ Contract: ____
Calcs made by: ____ date: ____ Calcs ck'd by: ____ date: ____	Calculations for: ____

Appendix A - Static Solutions for Free-swing Moorings.

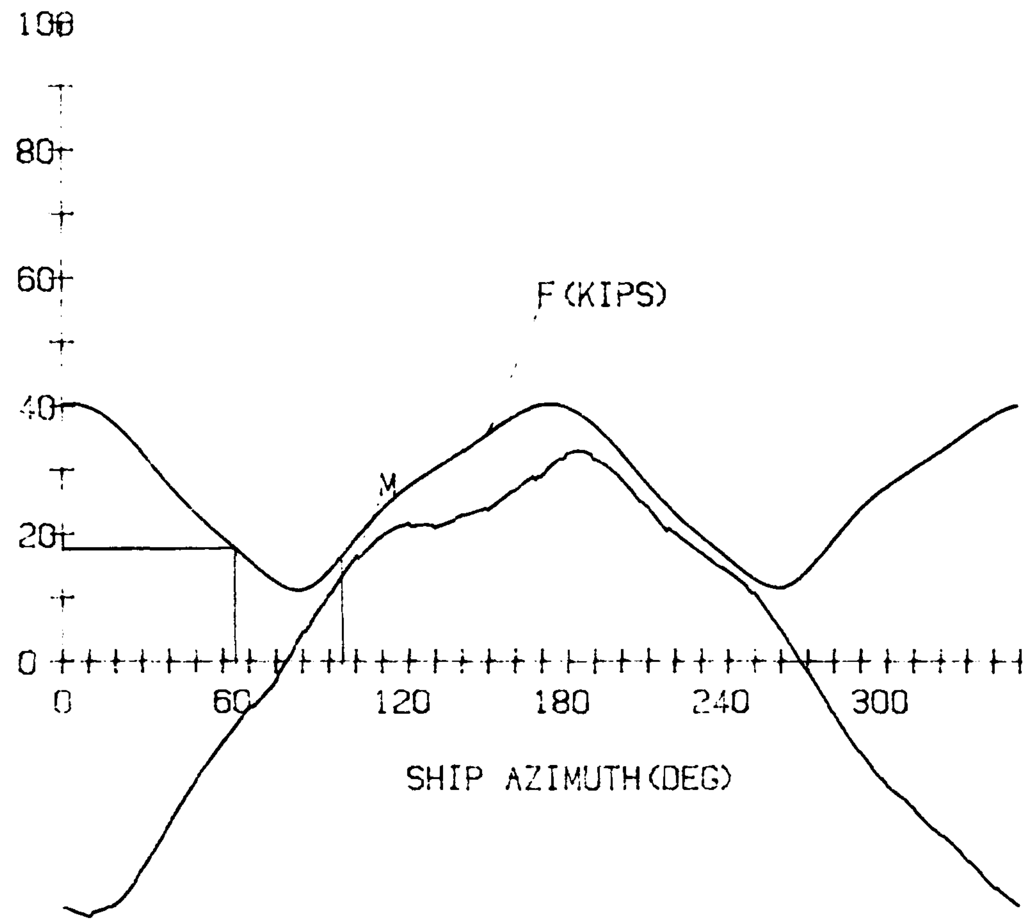
CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ______ Station: ______ E S R: ______ Contract: ______ Calculations for: ______
Calcs made by: ______ date: ______ Calcs ck'd by: ______ date: ______	




```
WIND SPEED(FPS),A(DEG)=120.0 30.0 CURRENT SPEED(FPS),A(DEG)=   2.5  22.5

 37 12.E+004 13.E+005 89.E+004 30.E+003 -2.E+004 -4.E+004 -1.E+003  32.4
255 -4.E+005 15.E+005 -7.E+005 -1.E+004 23.E+003 19.E+003 11.E+002  31.0
```

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ______ Station: ______
Calcs made by: ______ date: ______ Calcs ck'd by: ______ date: ______	E S R: ______ Contract: ______ Calculations for: ______



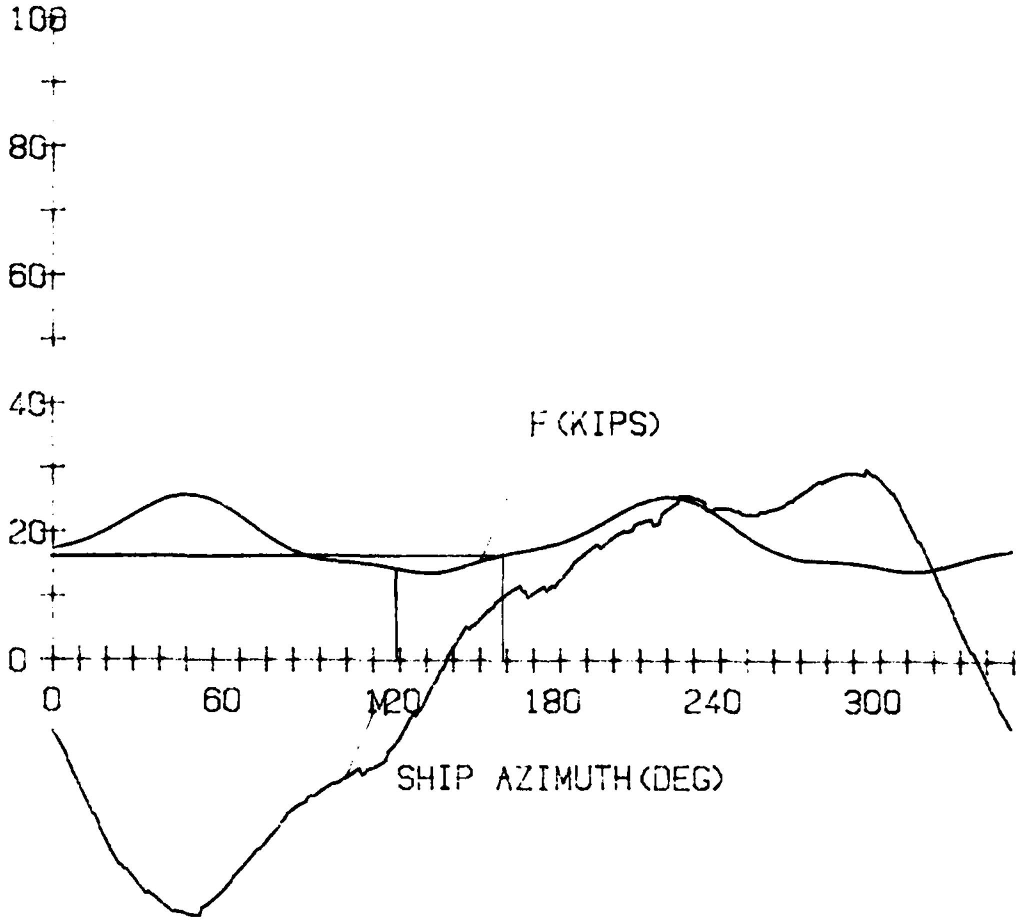
WIND SPEED(FPS),A(DEG)= 79.6135.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

85 '5.E+004 67.E+004 66.E+004 31.E+003 -2.E+004 -8.E+003 -8.E+002 11.3
278 -1.E+005 '2.E+005 -3.E+005 -2.E+004 27.E+003 12.E+003 48.E+001 '3.3

CHESAPEAKE DIVISION
Naval Facilities Engineering Command NDW
DISCIPLINE

Calcs made by: ____________ date: ______
Calcs ck'd by: ____________ date: ______

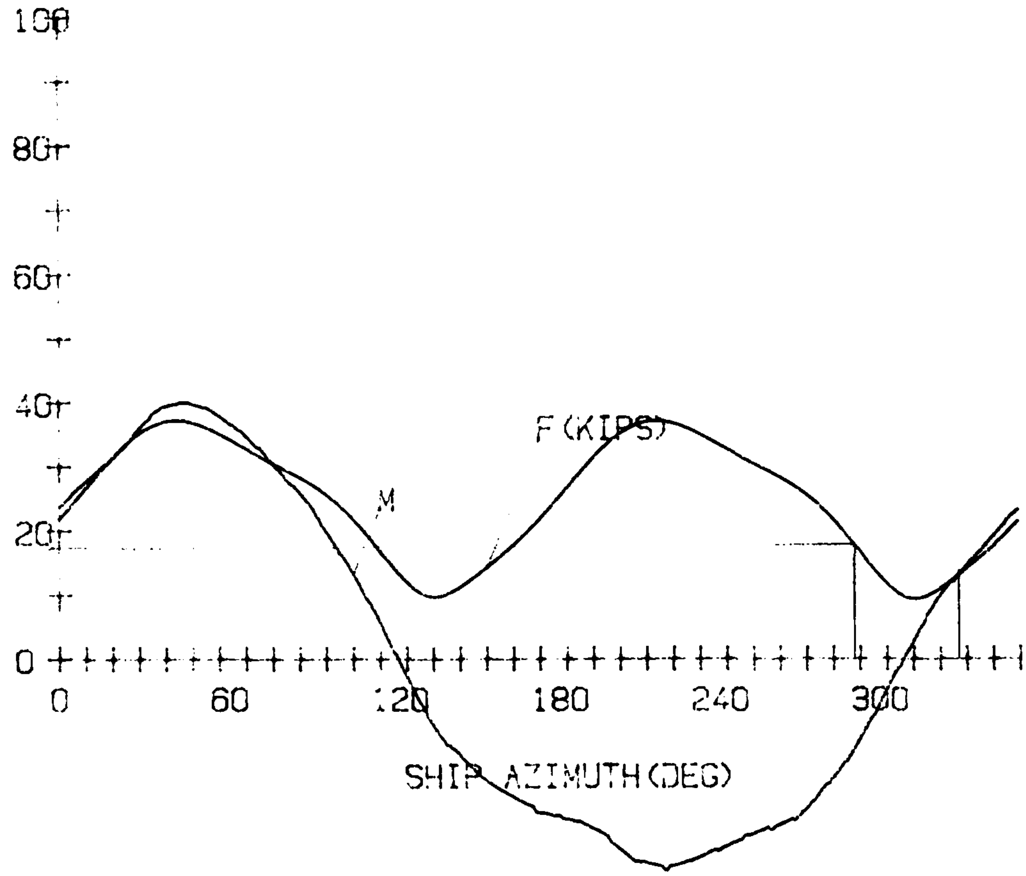
PROJECT: ____________
Station: ____________
E S R: ________ Contract: ____________
Calculations for: ____________



WIND SPEED(FPS),A(DEG)= 86.9180.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

148 81.E+003 83.E+004 -7.E+005 23.E+003 -2.E+004 -1.E+004 10.E+002 13.9
347 -2.E+004 74.E+004 86.E+004 -8.E+003 16.E+003 15.E+003 -1.E+003 16.2

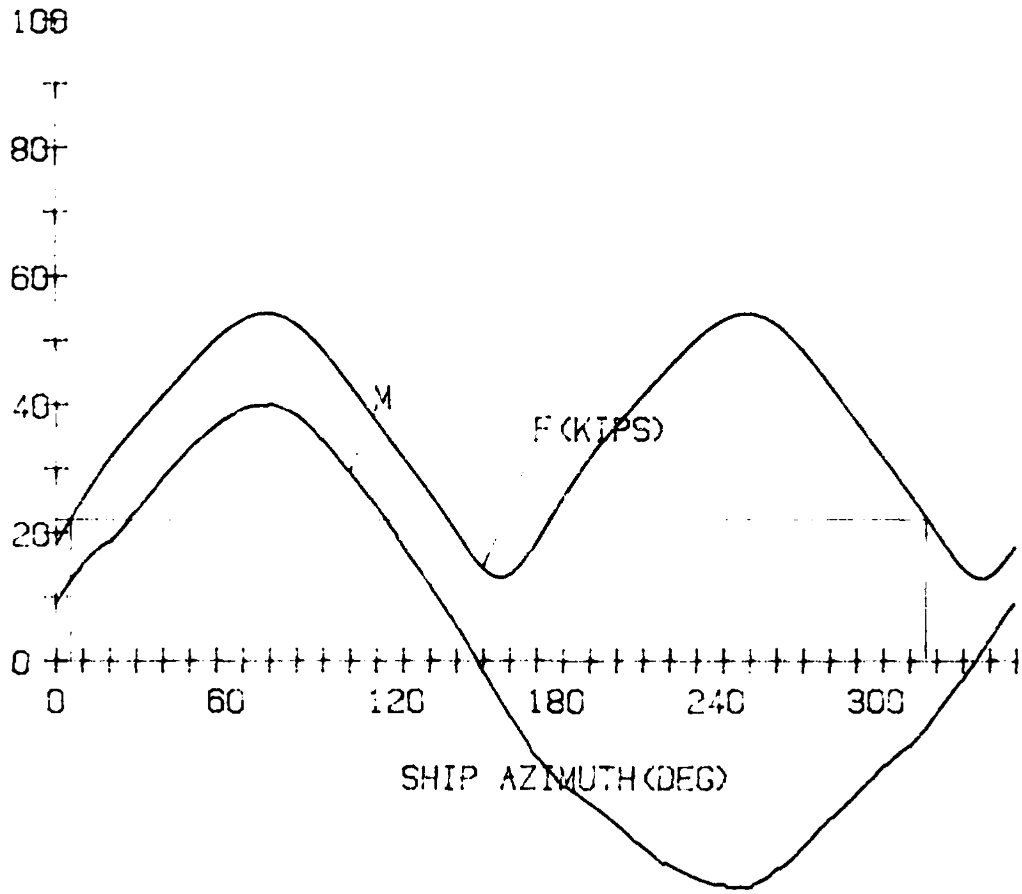
CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ____ Station: ____ E S R: ____ Contract: ____
Calcs made by: ____ date: ____ Calcs ck'd by: ____ date: ____	Calculations for: ____



WIND SPEED(FPS),A(DEG)= 75.6270.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

127 -7.E+004 -1.E+006 -3.E+005 21.E+002 -2.E+004 11.E+003 48.E+001 13.2
217 14.E+004 -6.E+005 66.E+004 -2.E+004 26.E+003 -9.E+003 -7.E+002 9.6

CHESAPEAKE DIVISION **Naval Facilities Engineering Command NDW** **DISCIPLINE**	**PROJECT:** ______ **Station:** ______ **E S R:** ______ **Contract:** ______ **Calculations for:** ______
Calcs made by: ______ **date:** ______ **Calcs ck'd by:** ______ **date:** ______	

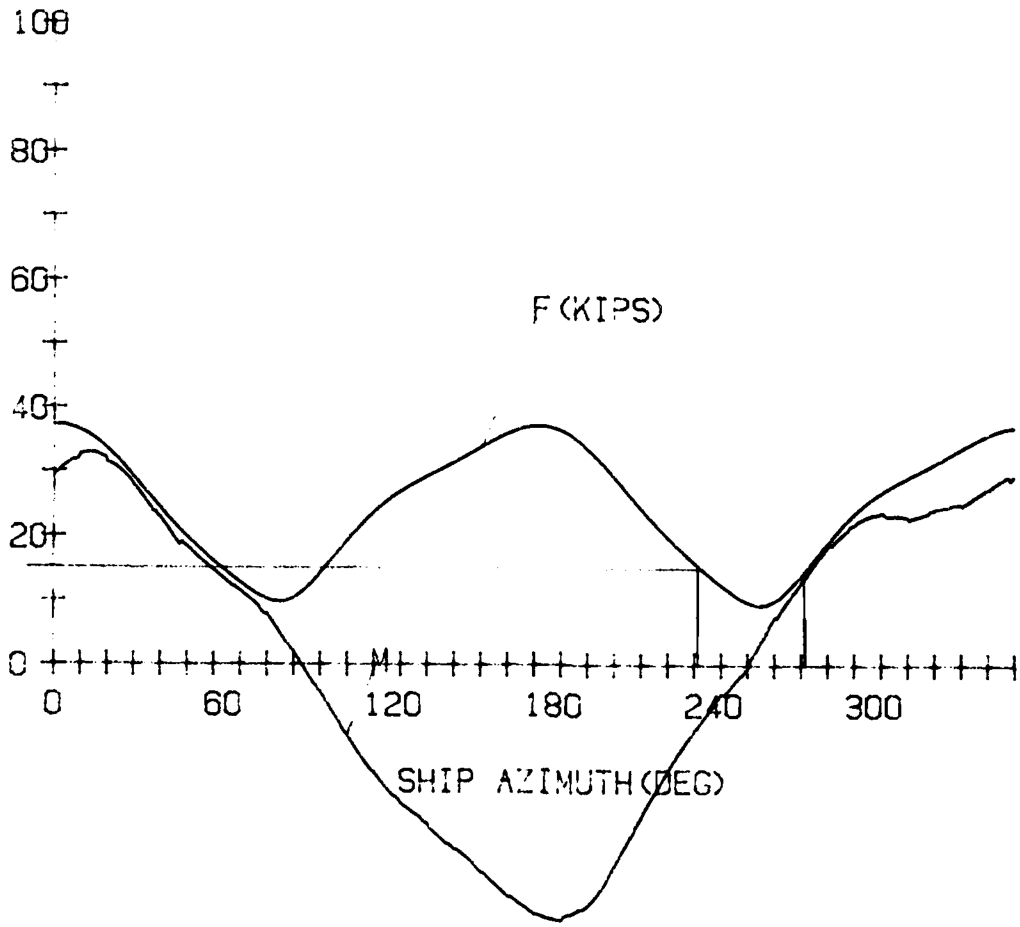


WIND SPEED(FPS),A(DEG)= 75.6315.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

136 -1.E+005 -6.E+005 -8.E+005 12.E+003 -2.E+004 12.E+003 13.E+002 15.3
345 50.E+003 -6.E+005 87.E+004 -1.E+004 17.E+003 -1.E+004 -1.E+003 12.9

GPO 885-653

CHESAPEAKE DIVISION **Naval Facilities Engineering Command NDW** **DISCIPLINE**	**PROJECT:** ______ **Station:** ______ **E S R:** ______ **Contract:** ______
Calcs made by: ______ **date:** ______ **Calcs ck'd by:** ______ **date:** ______	**Calculations for:** ______

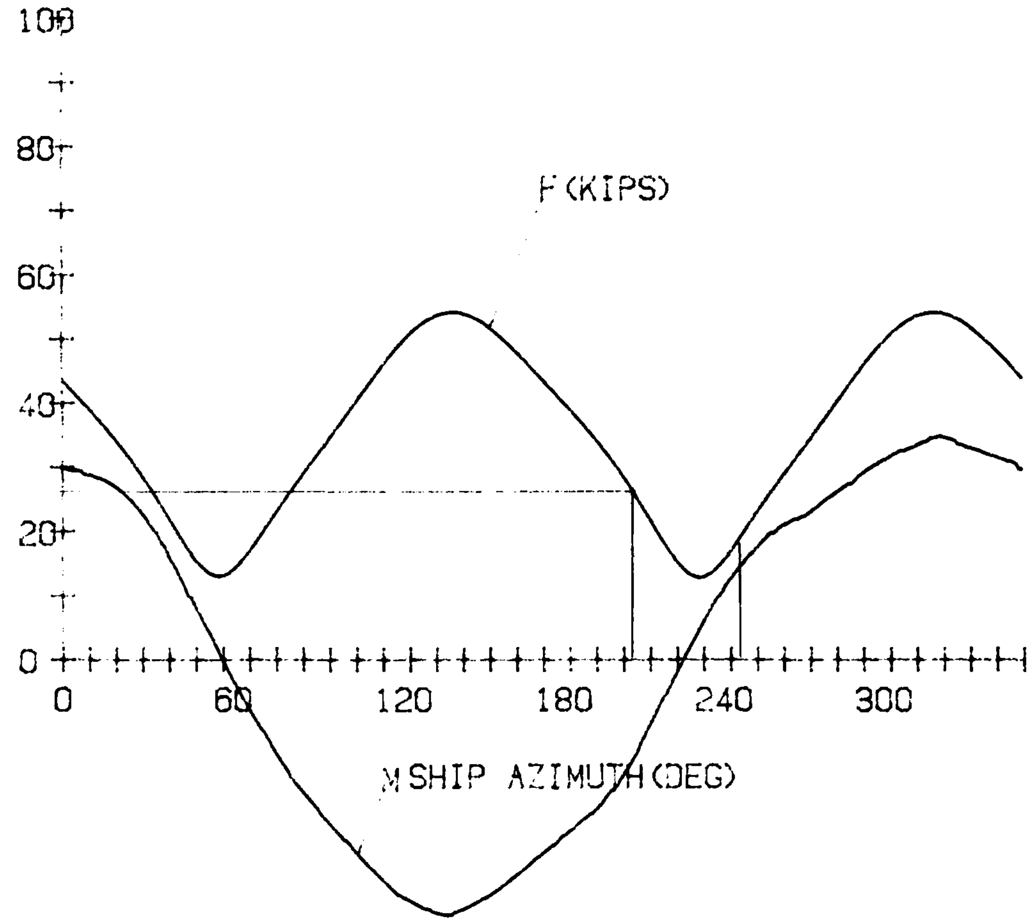


WIND SPEED(FPS).A(DEG)= 75.A3'5. CURRENT SPEED(FPS).A(DEG)= 2.5 202.5

```
 33 -2.E+004 11.E+005 -5.E+005 -2.E+004 27.E+003 10.E+003 62.E+001  11.1
 261 14.E+004 50.E+004 71.E+004 29.E+003 -..E+004 -7.E+003 -9.E+002   9.6
```


GPO 885-653

CHESAPEAKE DIVISION	PROJECT:
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: date:	Calculations for:
Calcs ck'd by: date:	

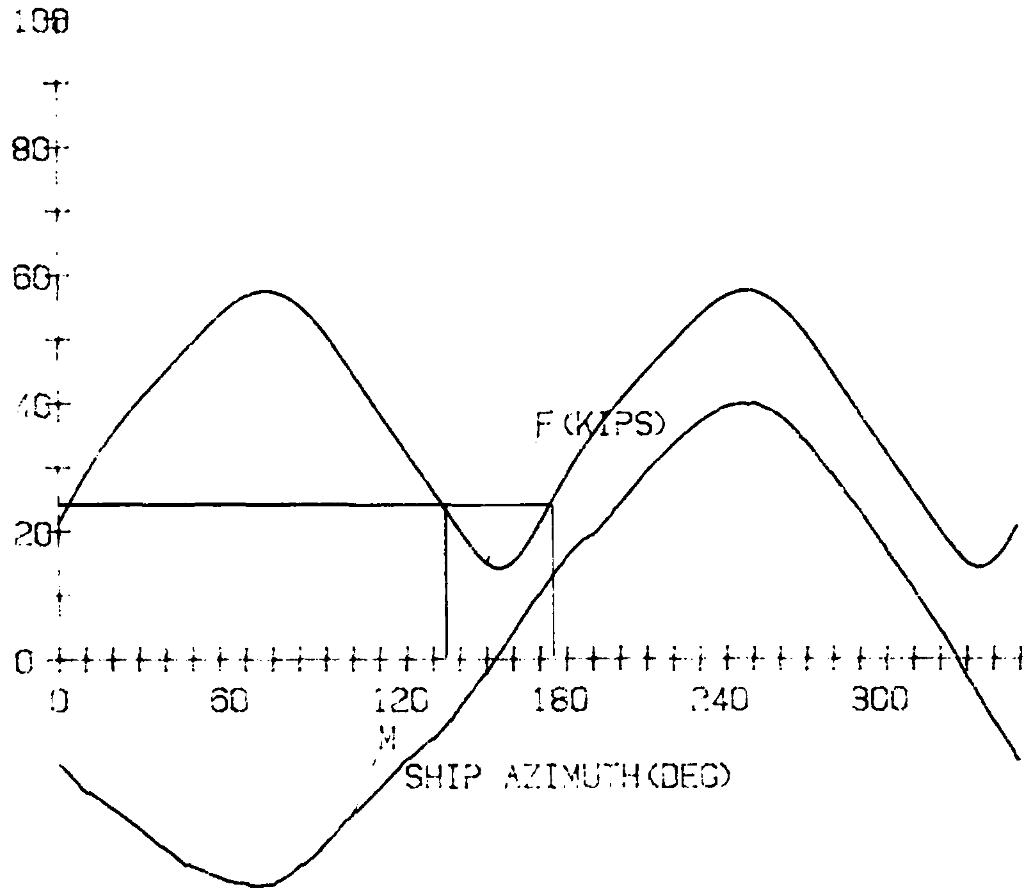


WIND SPEED(FPS),A(DEG)= 75.6270.0 CURRENT SPEED(FPS),A(DEG)= 2.5 202.5

```
 60 -9.E+004 97.E+004 -9.E+005 -1.E+004 17.E+003 12.E+003 14.E+002  13.9
233 16.E+004 66.E+004 81.E+004 21.E+003 -1.E+004 -1.E+004 -1.E+003  13.8
```


GPO 885-653

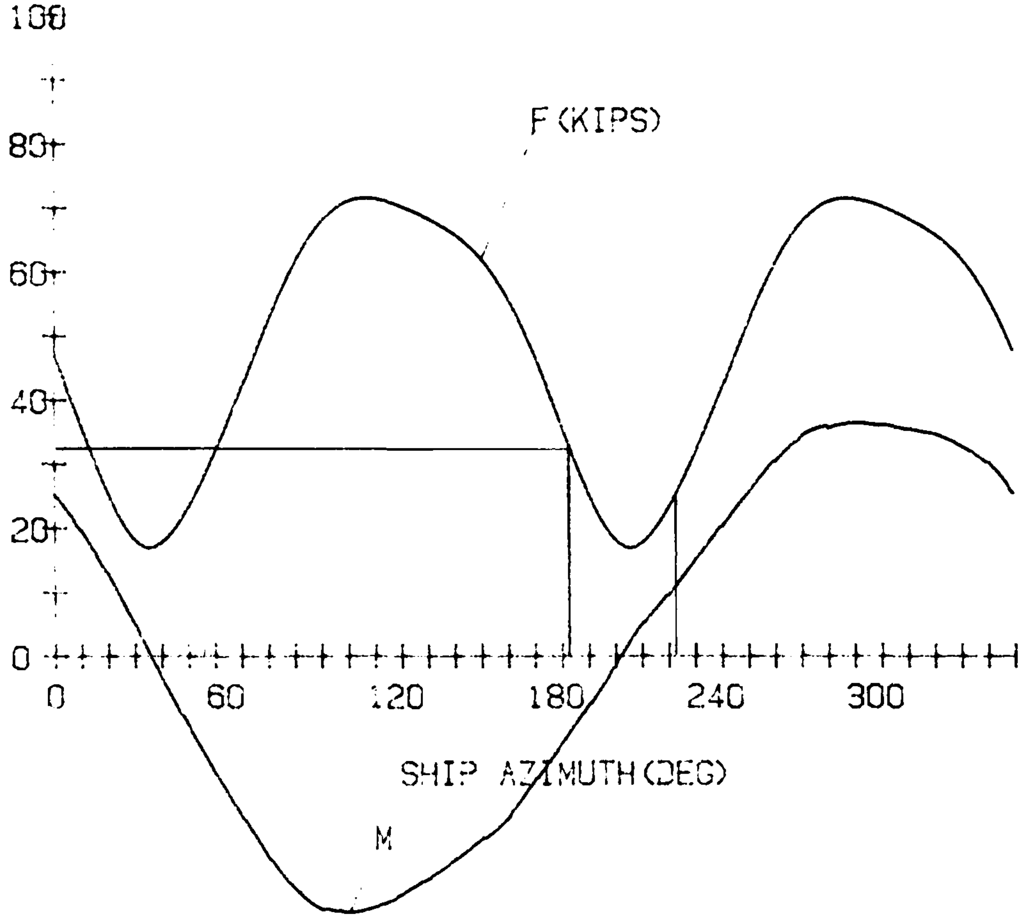
CHESAPEAKE DIVISION	PROJECT:
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: date:	Calculations for:
Calcs ck'd by: date:	



WIND SPEED(FPS),A(DEG)= 79.6135.0 CURRENT SPEED(FPS),A(DEG)= 2.5 202.5

154 13.E+004 -7.E+005 58.E+004 -1.E+004 19.E+003 -1.E+004 -1.E+003 14.1
337 -1.E+005 -8.E+005 -8.E+005 12.E+003 -2.E+004 13.E+003 12.E+002 16.3

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT:
Calcs made by: date:	Station:
Calcs ck'd by: date:	E S R: Contract:
	Calculations for:

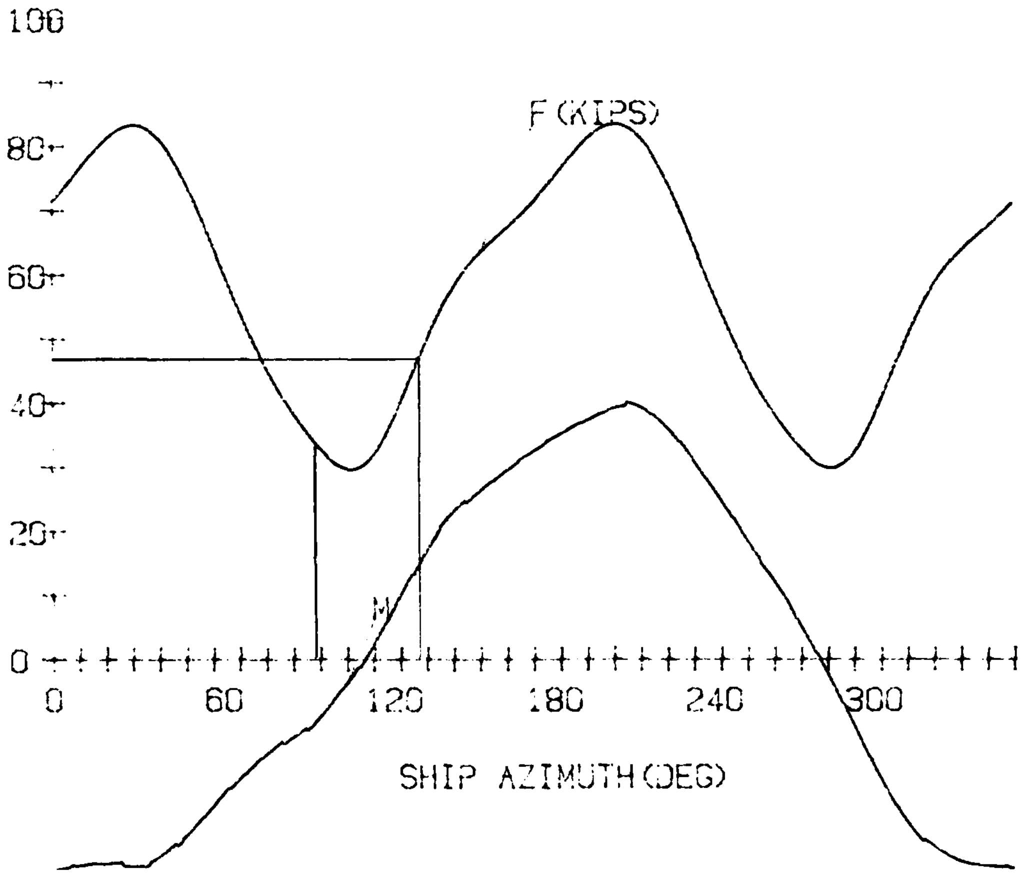


WIND SPEED(FPS),A(DEG)= 86.3225.0 CURRENT SPEED(FPS),A(DEG)= 2.5 202.5

.6 -1.E+005 51.E+004 -4.E+005 -5.E+002 56.E+002 15.E+003 17.E+002 16.9
212 26.E+003 47.E+004 26.E+004 82.E+002 -4.E+003 -1.E+004 -1.E+003 17.4

GPO 885-653

CHESAPEAKE DIVISION	PROJECT:
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: date:	Calculations for:
Calcs ck'd by: date:	



[illegible] SPEED(FPS),A(DEG)=120.0 30.0 CURRENT SPEED([illegible]

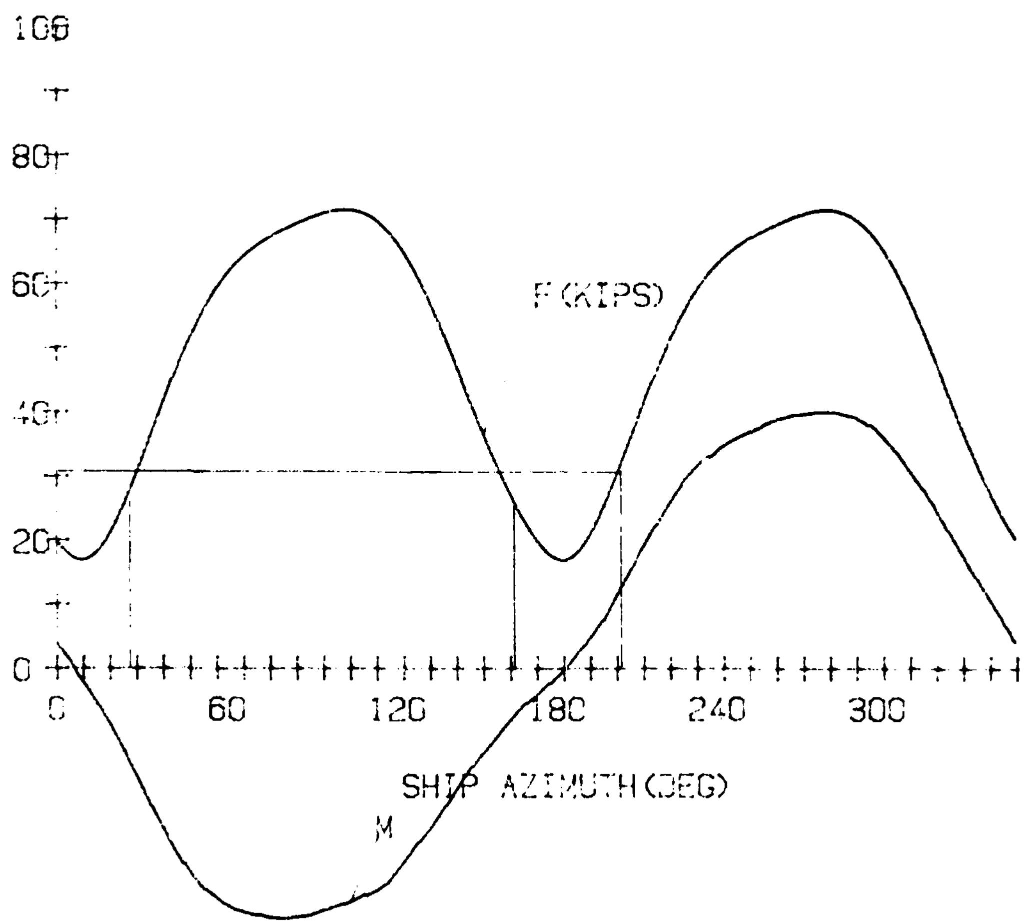
[illegible] E+004 [illegible].E+006 10.E+004 [illegible].E+004 [illegible]
[illegible] E+004 [illegible].E+006 [illegible].E+004 [illegible]

GPO 885-653

CHESAPEAKE DIVISION
Naval Facilities Engineering Command NDW
DISCIPLINE

Calcs made by: ______ **date:** ______
Calcs ck'd by: ______ **date:** ______

PROJECT: ______
Station: ______
E S R: ______ **Contract:** ______
Calculations for: ______



WIND SPEED(FPS),A(DEG)= 96.3 180.0 CURRENT SPEED(FPS),A(DEG)= 2.5 202.5

-1.E+005 -4.E+005 -4.E+005 42.E+002 -7.E+003 15.E+003 17.E+002 17.2
10.E+004 -4.E+005 32.E+004 -6.E+003 57.E+002 -1.E+004 -1.E+003 17.0

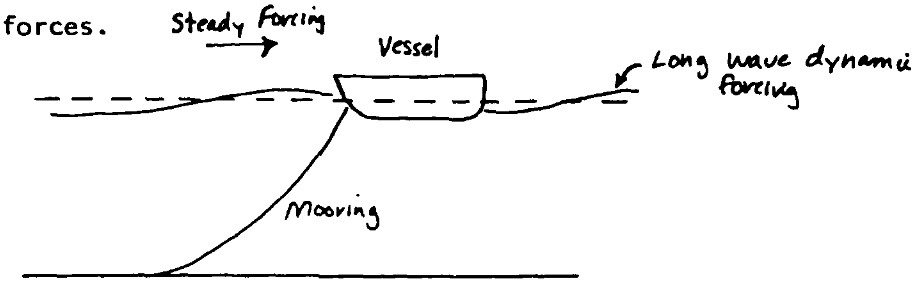
CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: ______ Station: ______ E S R: ______ Contract: ______
Calcs made by: ______ date: ______ Calcs ck'd by: ______ date: ______	Calculations for: ______

Appendix B - Numerical Model of Mooring Dynamics

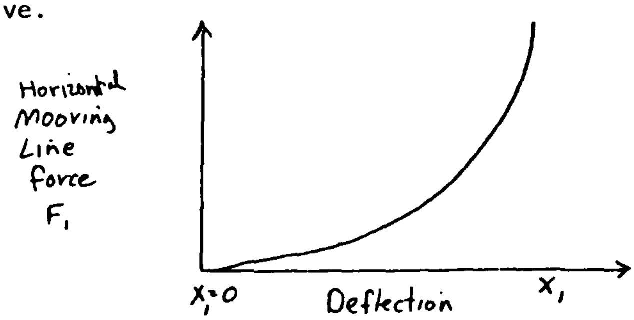
CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Mooring Dynamics - Long Waves Station: E S R: Contract:
Calcs made by: Seelig date: 9 DEC 82 Calcs ck'd by: date:	Calculations for: ~~Problem Statement &~~ Setup

Forces on mooring consist of two types, static and dynamic. Static forces can be determined from DM 26 or computer programs, such as STATMOR. The purpose of this analysis is to predict dynamic mooring line forces for the case of long waves.

In this simple analysis the system consists of a mooring, vessel, steady and dynamic forces.



Steady forces must first be determined and the entire mooring line system by statically analyzed with the CHESDIVNAVFACENGCOM catenary program to determine the load deflection curve.



In this analysis the load-deflection curve is represented by the the power formula:

$$F1 = K1*X1 + K2*X1^2 + \ldots \qquad (1)$$

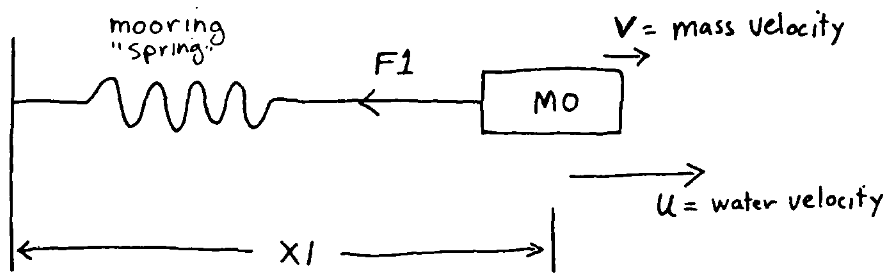
where X1 is the deflection from the neutral position and F1 is the horizontal component of the mooring line force at the vessel. Here only the first two terms in Eq (1) have been used.

In this analysis the ship is represented by a mass, MO, that includes the ship mass, M, and the added mass of water around the ship. This total mass is given by:

$$MO = C_H \ M \qquad (2)$$

where C_H is a mass coefficient determined from the curves on the following page (found in DM-25.1).

The analyzed system is then treated as a damped forced mass restrained by a non-linear spring:



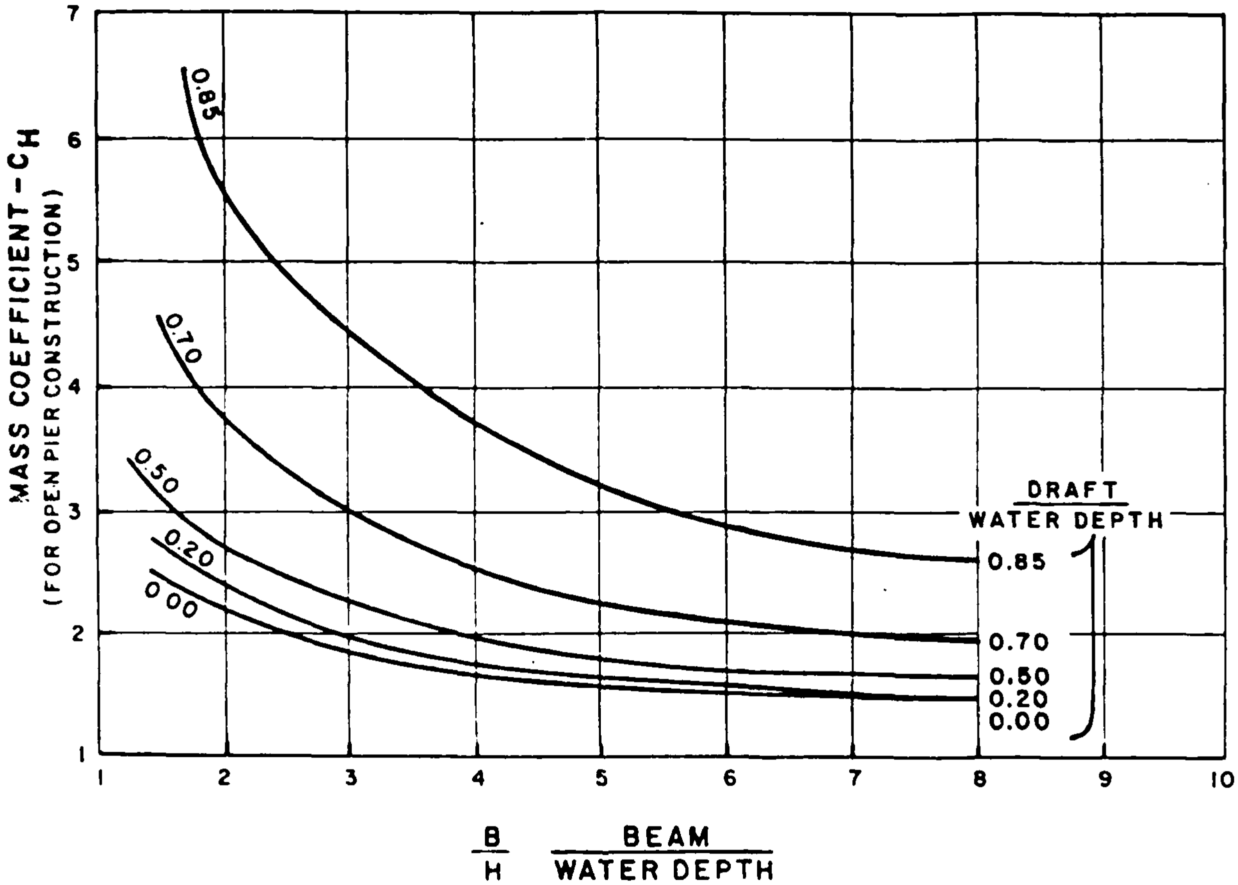
V is the velocity of the vessel at any instant in time and A is the acceleration of the mass (only sway, surge or heave motion are considered in this analysis).
U is the velocity of water at the vessel induced by long waves, such as harbor oscillations or surf beat. These long waves may be considered as "shallow water" waves, so:

$$U = a \sqrt{\frac{g}{d}} \ \sin(2 \pi t/T) \qquad (3)$$

where a is the long wave amplitude, g is the acceleration due to gravity, d is water depth, t is time and T is period of the long wave (see the "Shore Protection Mannual", US Army Corps of Engineers, CERC, 1977).

If V is the velocity of the vessel and U is the velocity of the water, then the relative water velocity is given by:

$$W = U - V \qquad (4)$$



(after DM-25.1, Figure 47)

Recommended Ship Mass Coefficients
(added mass of water included)

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Mooring Dynamics Station: E S R: Contract:
Calcs made by: Seelig date: 9 Dec 82 Calcs ck'd by: date:	Calculations for:

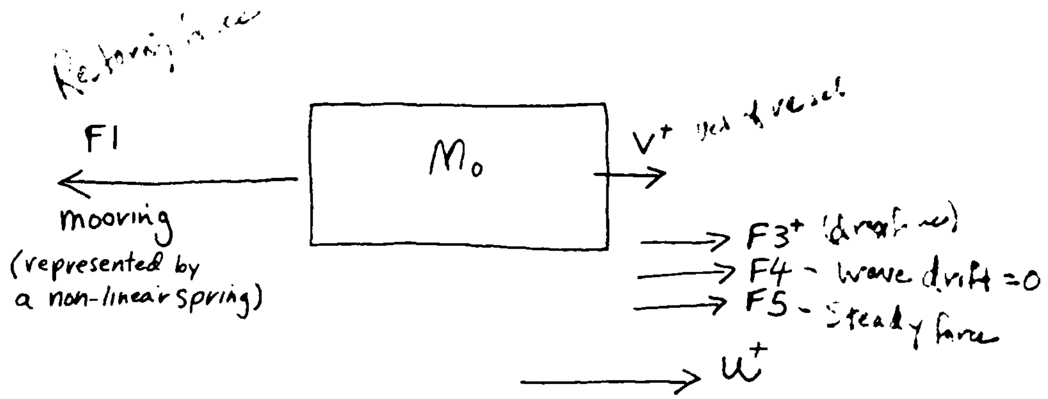
The drag force on the vessel due to relative water motion is taken as:

$$F3 = \frac{\rho}{2} C_d A \; W|W| \tag{5}$$

where ρ is the fluid density, A is the projected area of the body in the direction of flow and C_d is a drag coefficient. Typical values of C_d for idealized shapes are given in the figure on the next page.

Steady forces are due to uniform wind and currents, F5, and a "wave drift force" due to the change of wind wave height around the ship. This wave drift force, F4, can be determined using the method of Remery et al. (1973, OTC Paper No. 1741).

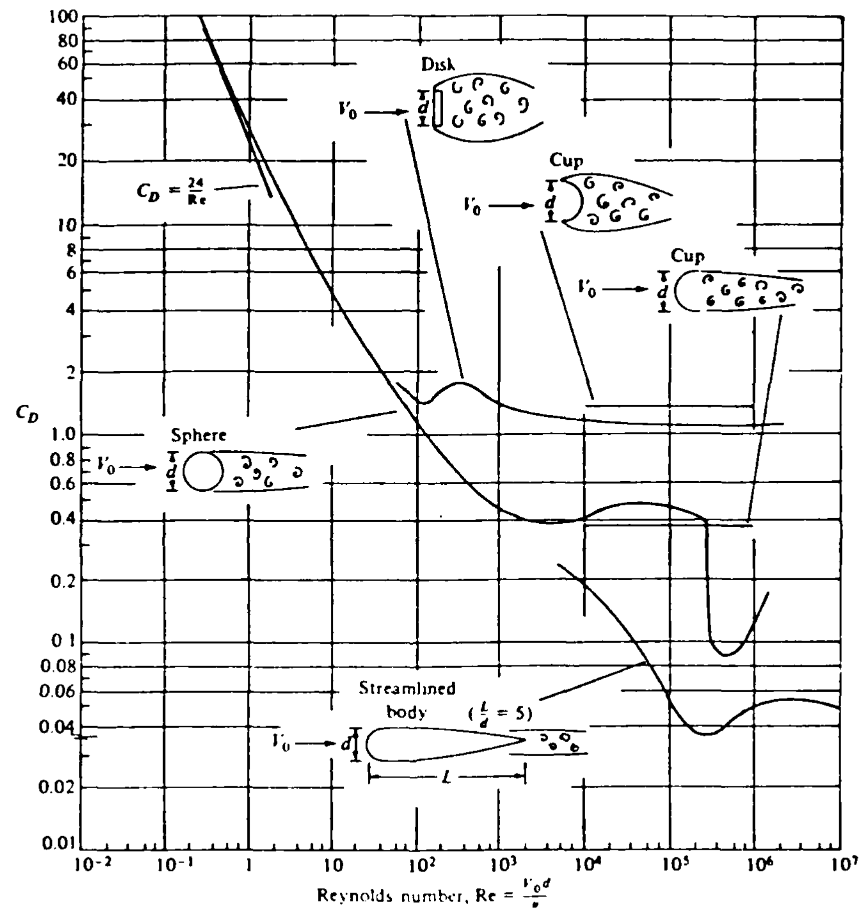
A sketch of the modeled system with forces is shown below:



u = Current velocity

$W = u - v$

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Mooring Dynamics Station: E S R: Contract:
Calcs made by: Seelig date: 9 Dec 82 Calcs ck'd by: date:	Calculations for: Drag Coefficients



Drag Coefficients for Idealized Shapes

(after Roberson and Crowe, Engineering Fluid Mechanics, Houghton Mifflin Co., Boston, Mass., 1975)

At any given instant in time the sum of forces acting on the body is:

$$F = F1 + F2 + F3 + F4 + F5 \qquad (7)$$

where the location is X1 and ship velocity is V. To find the ship position at some very small time step into the future, Δt, the equation of motion is first used to find the ship acceleration:

$$A = \frac{F}{MO} \qquad (8)$$

The change in distance, $\Delta X1$, is then found from the following finite-difference equation:

$$\Delta X1 = V \Delta t + A\,(\Delta t^2/2) \qquad (9)$$

and new vessel location given by:

$$X1' = X1 + \Delta X1 \qquad (10)$$

The above proceedure is applied in very small time steps to determine the vessel position and horizontal forces in the mooring as a function of time. In this analysis, the forcing is assumed to be periodic Eq(3) to allow easy computation on a desk-top computer. This is assumed to be adequate for a first "quick look".

Probably the most difficult portion of the analysis is determining the vessel coefficients to be used as input. These can be obtained from DM26 or other sources of marine architecture. When in doubt, I recommend that several values of the coefficients over a reasonable range be tested to determine if the value significantly influences results.

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	**PROJECT:** Mooring Dynamics **Station:**
	E S R: **Contract:**
Calcs made by: Seelig **date:** 22 Dec82	**Calculations for:** Program Listing
Calcs ck'd by: **date:**	

```
10 PLOTTER IS 1
20 OPTION BASE 1
30 DEG
40 DIM T(200),Y(200),F(200)
50 DISP "SHIP DISP(LT)";
60 INPUT M0
70 DISP "MASS COEFF(CH)";
80 INPUT C
110 M0=C*2240/32200*M0
120 DISP "CROSS-SECT AREA(FT2)";
130 INPUT A9
160 DISP "DRAG COEFF";
170 INPUT C
180 DISP "STEADY FORCE(K)";
190 INPUT F5
220 DISP "MOORING K1=";
230 INPUT K1
240 DISP "K2=";
250 INPUT K2
280 DISP "TP(SEC)";
290 INPUT P2
300 P1=P2*.1
301 DISP "MAX VELOCITY(FPS)="
310 INPUT A2
320 L=1.94*C*A9/1000
330 F=1
331 C1=0
332 D2=1000
337 T1=0
340 F4=0
341 F4=0
350 F6=F4+F5
360 X0=(-K1+SQR(K1^2-4*K2*F6))/
    (2*K2)
370 T9=.04*P1
380 T8=T9*T9*.5
390 S=2*PI/P2
391 D5=
400 X1=X0+.0001
410 F8=0
411 D6=-1000
412 D7=1000
420 T0=0
430 M=0
440 FOR I=1 TO 994
450 T0=T0+T9
460 U=A2*SIN(S*T0)
470 V=(X1-X0)/T9
```


GPO 889-526

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	**PROJECT:** Mooring Dynamics
	Station:
	E S R: **Contract:**
Calcs made by: Seelig **date:** 22 Dec 82	**Calculations for:** Program Listing
Calcs ck'd by: **date:**	

```
471 X0=X1
472 X2=ABS(X1)
477 S1=X2/X1
480 F1=-((K1*X2+K2*X2*X2)*S1)
490 W=U-V
510 F3=C*W*ABS(W)*C5
520 A=(F1+F3+F4+F5)/M0
530 X1=X0+V*T9+A*T8
542 T3=T3+T9
543 IF I<4 THEN GOTO 640
550 N=I MOD 10
560 IF N>0 THEN GOTO 640
562 IMAGE 4(DDD.DD,1X)
570 M=M+1
580 T(M)=T3
590 X(M)=U
595 F1=-F1
600 IF F1>01 THEN X5=T(M)
601 IF F1>01 THEN 01=F1
602 IF F1<02 THEN 02=F1
610 F(M)=F1
620 IF F1>F8 THEN F8=F1
640 IF X1>D6 THEN D6=X1
641 IF X1<D7 THEN D7=X1
642 NEXT I
643 D7= 5*(01+02)
648 PRINT USING 657 ; 01,02,D6,D
7
650 IMAGE "T=",DDD ," F=",DDDD D
D
653 IMAGE 4(DDDD DDD)
660 CLEAR
670 PEN 1 @ GCLEAR
680 SCALE -100,T(M),-5,30
681 S3= 1*P2
684 XAXIS 0,S3,0 T(M)
686 YAXIS 0,5,0,30
688 MOVE T(4),F(4)
692 FOR I=4 TO M
693 DRAW T(I),F(I)
694 NEXT I
695 MOVE 0,0
696 FOR I=1 TO M
697 I0=I MOD 2
698 IF I0=0 THEN MOVE T(I),X(I)
699 IF I0>0 THEN DRAW T(I),X(I)
700 NEXT I
704 MOVE 105,25
706 LABEL "25"
708 I2= 75*M
709 01=01+2
710 MOVE X5,01
715 LABEL "F"
716 X0=X(I2)-2 5
717 MOVE T(I2),X0
719 LABEL "U"
722 X0=T(M)* 4
725 MOVE X0,27
728 LABEL "F&U VS TIME"
740 END
```

CHESAPEAKE DIVISION	PROJECT: Mooring Dynamics
Naval Facilities Engineering Command NDW	Station:
DISCIPLINE	E S R: Contract:
Calcs made by: Seelig date: 22 Dec82	Calculations for: Example
Calcs ck'd by: date:	

Take the case of a large submarine and power barge attached to mooring 1-N in Sasebo Harbor, Japan.

GIVEN: The ship displacement is 7300 long tons.
The added mass coefficient is 2.6 (see the theory section).
The ship cross-section flow area is 700 square feet.
The drag coefficient is 0.1 (see the theory section).

FIND: The maximum force in the mooring at the buoy for a periodic reversing current with 2.6 fps maximum. The period of this wave is taken as 450 seconds. A light wind is assumed, which produces a 5 kip steady force on the vessel.

INPUT: The above information is input to the program in the following format:

```
SHIP DISP(LT)?
7300
MASS COEFF(CM)?
2.6
CROSS-SECT AREA(FT2)?
700
DRAG COEFF?
.1
STEADY FORCE(K)?
5
MOORING K1=?
[illegible]
K2=?
[illegible]
T(SEC)?
450
MAX VELOCITY(FPS)=?
2.6
```


GPO 889-826

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Mooring Dynamics Station: E S R: Contract:
Calcs made by: Seelig date: 22 Dec 82 Calcs ck'd by: date:	Calculations for: Example

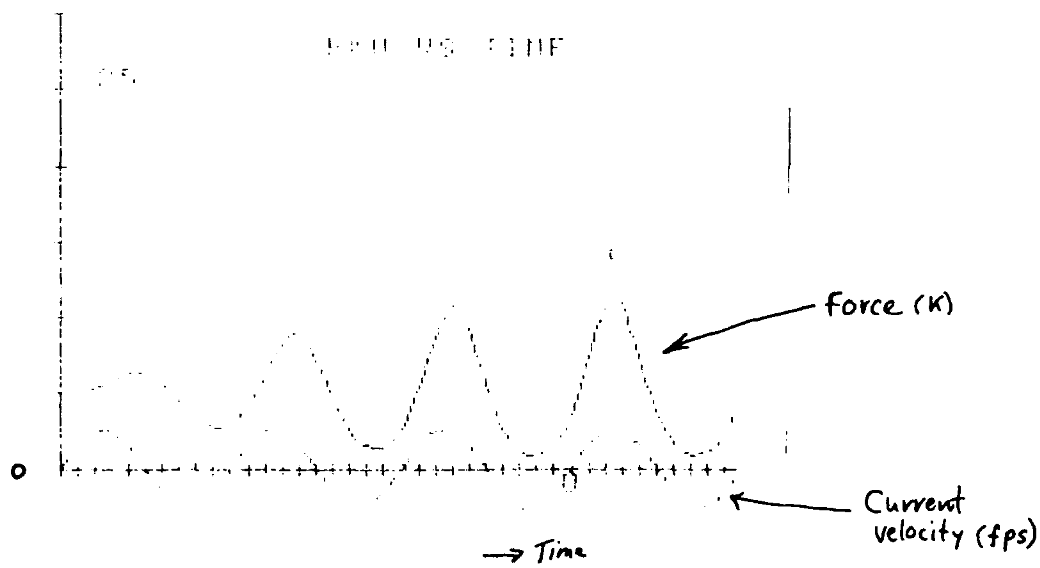
OUTPUT: One line of printed output is available that includes:

maximum and minimum horizontal forces at the buoy (kips)

maximum and minimun excursion of the buoy (feet)

The watch circle is the extent of this excursion, which is 14 feet for this case.

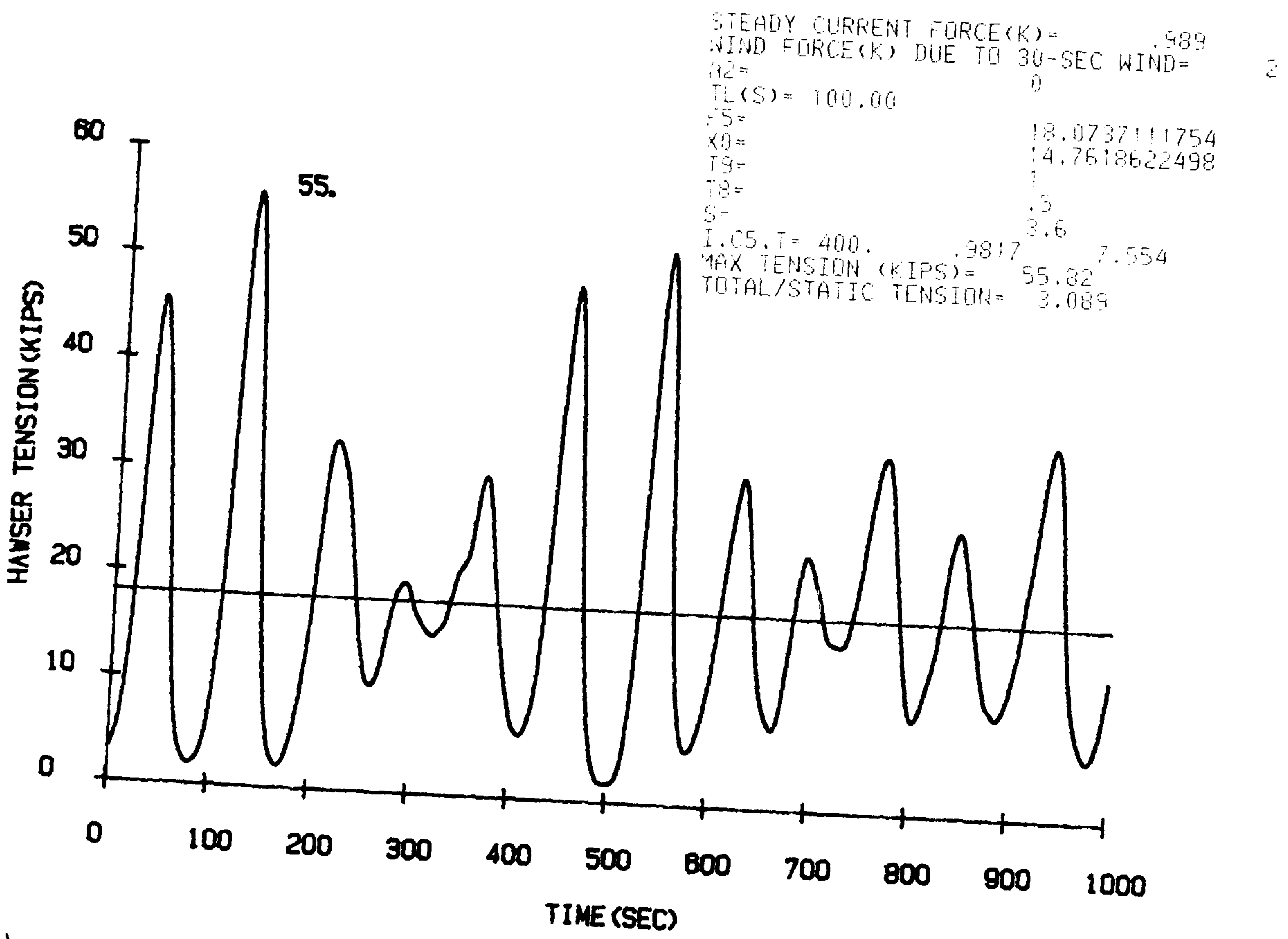
A plotted time history of the forcing currents, U, (shown by the dashed line) and the resulting forces (F) are also produced (see below).



In this example the first wave is predicted to produce little force in the mooring because of interia in the system. However, subsequent waves produce significant forces due to resonance in this case. More detailed analysis shows that the magnitude of the maximum current, wave period and magnitude of the steady forcing are all inportant in determing the amount of dynamic forcing and motion of the vessel.

Calcs made by: date:	PROJECT:
Calcs ck'd by: date:	Station:
	E S R: Contract:
	Calculations for:

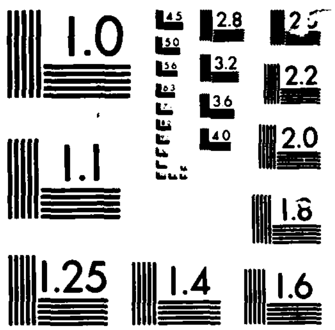
Appendix C - Dynamic Solutions



0° Wind Azimuth

AD-A168 459 DESIGN CALCULATIONS OF THE HURRICANE MOORINGS AT NAVAL STATION MAYPORT FL..(U) NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON DC CHESAPEAKE.. C A HUBLER DEC 84 2/2

UNCLASSIFIED CHES/NAVFAC-FPO-1-84(46) F/G 13/10 NL



MICROCOPY CHART

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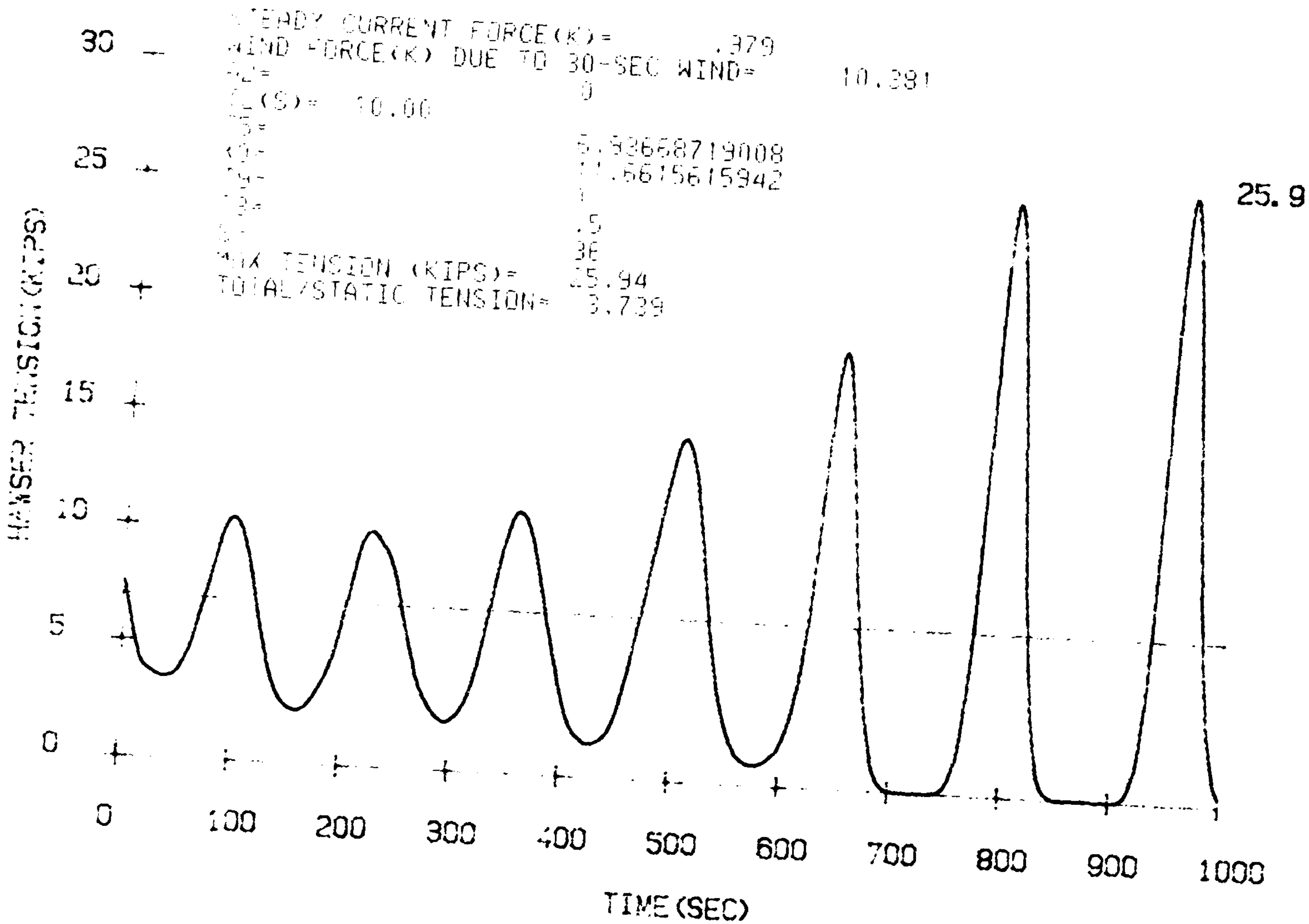

45° Wind Azimuth

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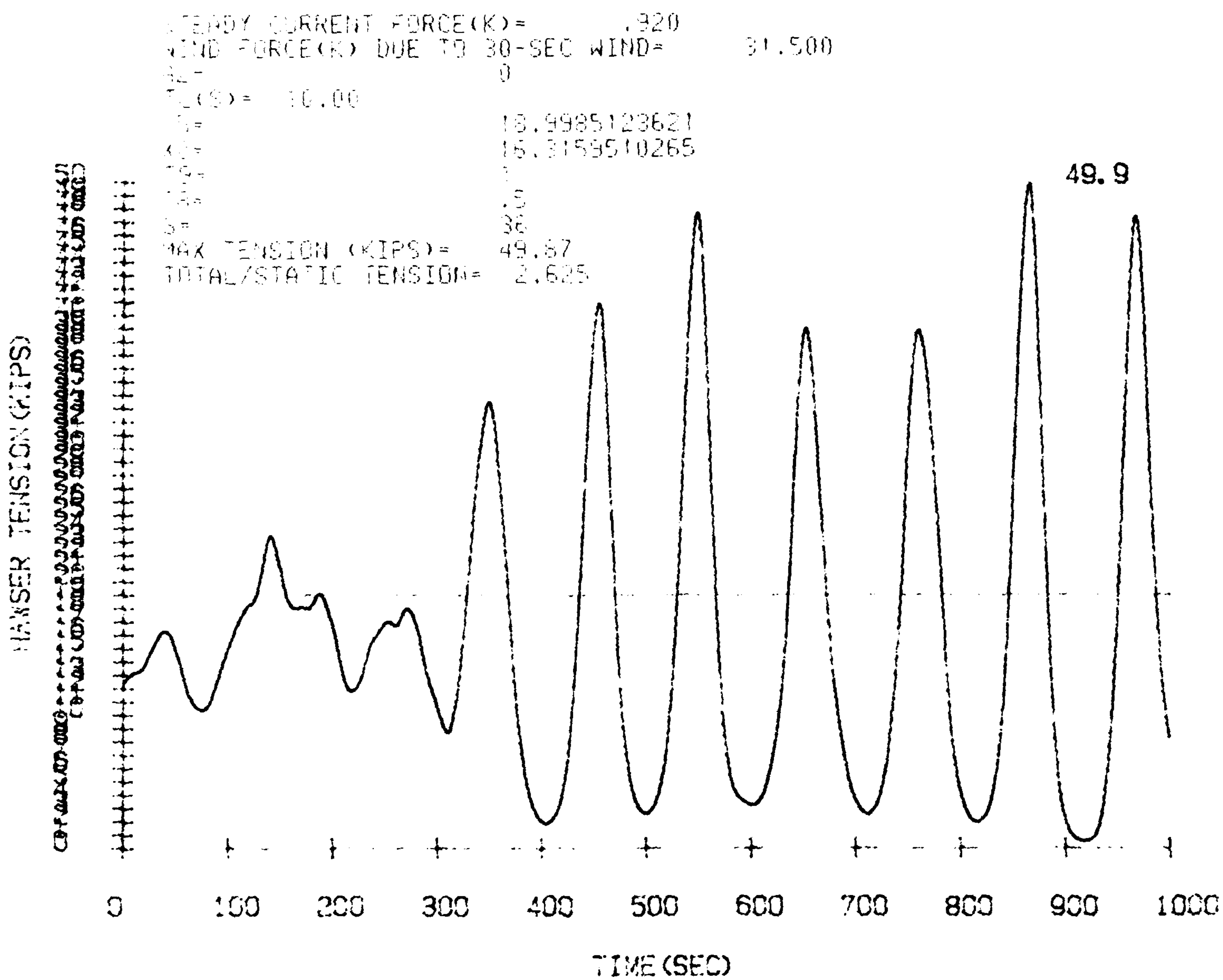
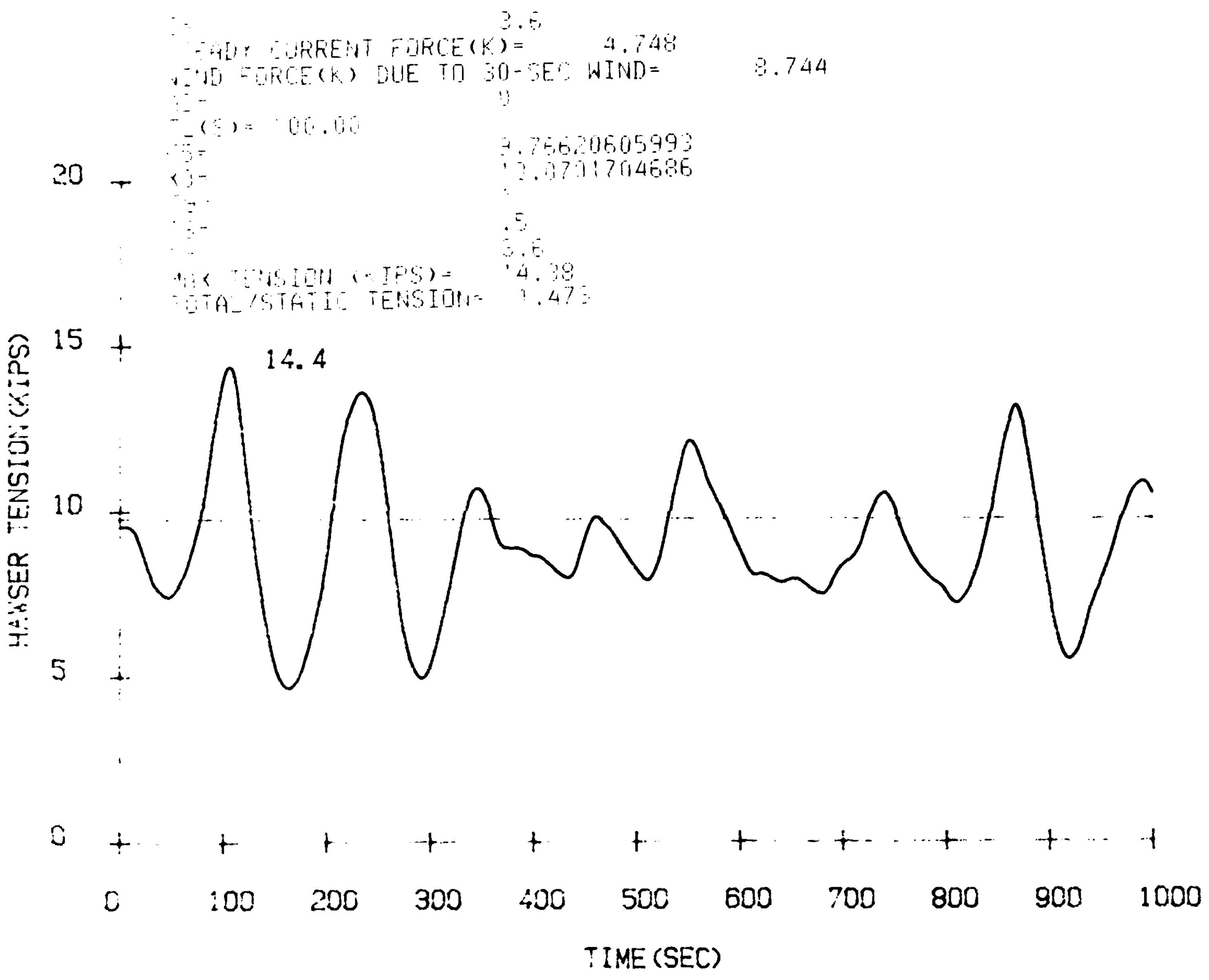


90° Wind Azimuth

Page G30



135° Wind Azimuth

```
STEADY CURRENT FORCE(K)=        .980
WIND FORCE(K) DUE TO 30-SEC WIND=        9.800
Q2=                         0
TL(S)=  10.00
F5=
K9=                         6.60426679721
T9=                         11.4722222146
T8=                         1
S=                          .5
                            36
MAX TENSION (KIPS)=         18.75
TOTAL/STATIC TENSION=       2.839
```

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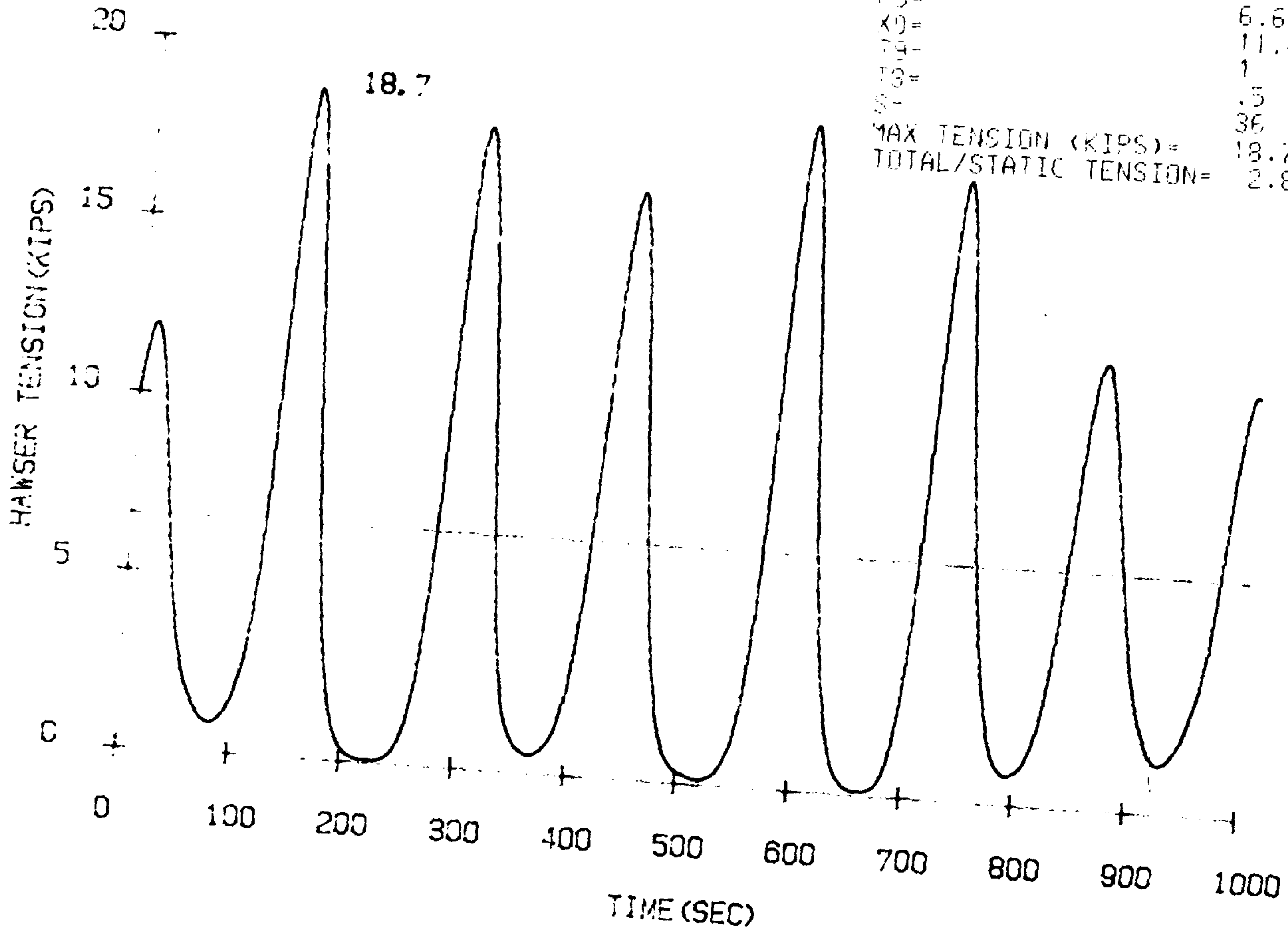
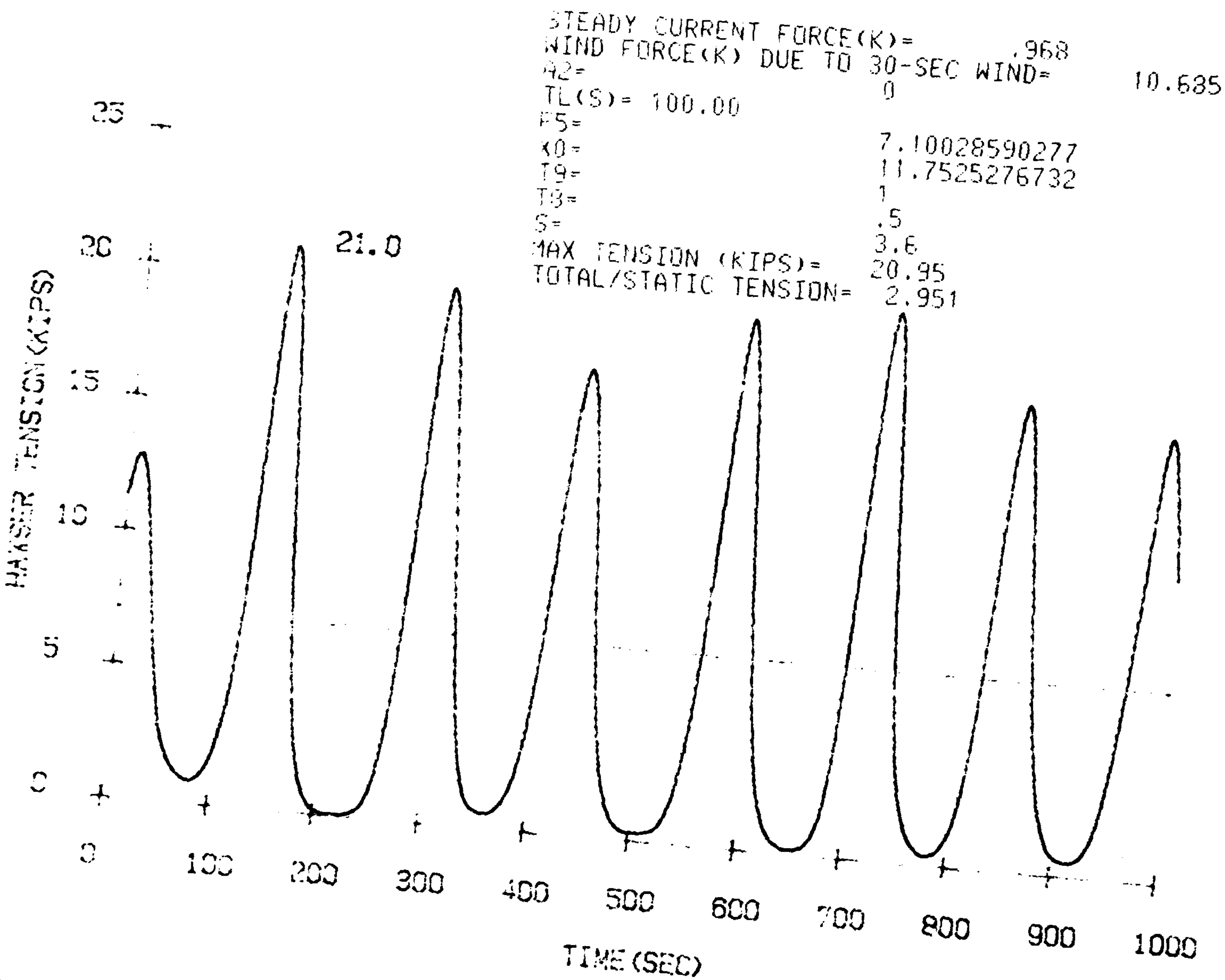
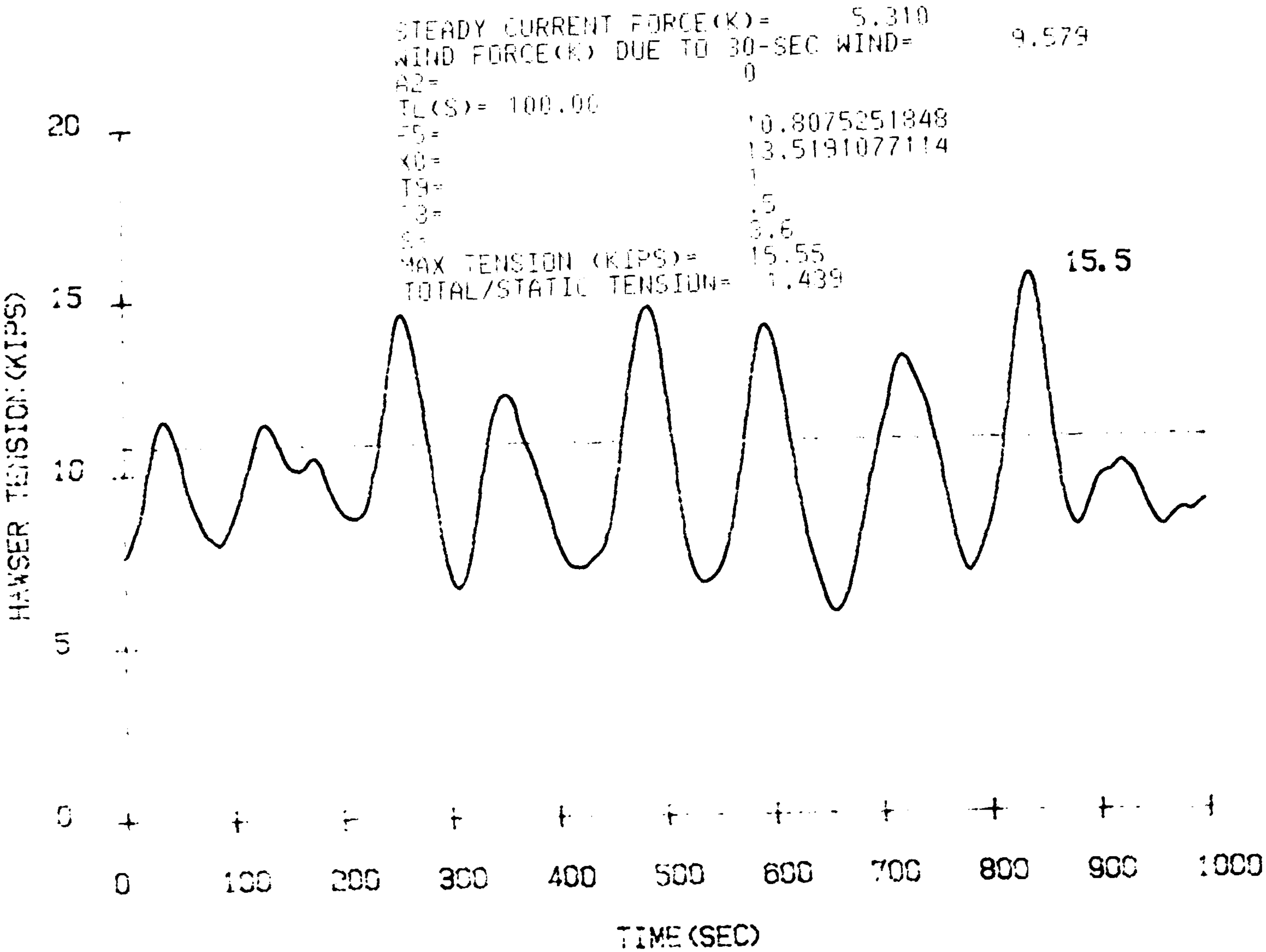


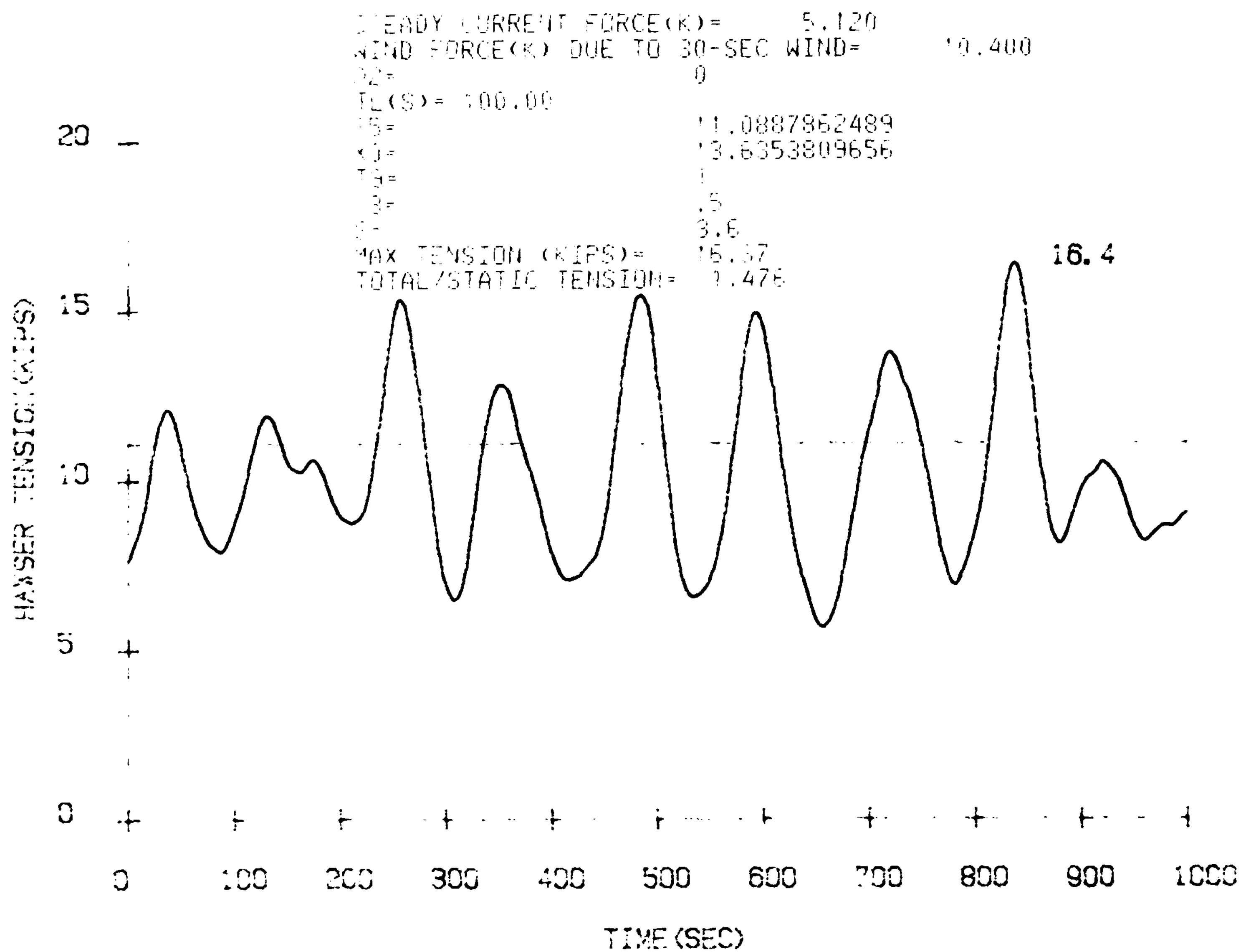
180° Wind Azimuth



225° Wind Azimuth



270° Wind Azimuth



315° Wind Azimuth

CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE	PROJECT: Station: E S R: Contract:
Calcs made by: date: Calcs ck'd by: date:	Calculations for:

Appendix D - Law Engineering Testing Co Report

LAW ENGINEERING TESTING COMPANY
geotechnical, environmental & construction materials consultants
3901 CARMICHAEL AVENUE
P.O. BOX 5728 • JACKSONVILLE, FLORIDA 32207
(904) 396-5173

November 2, 1982

RECEIVED
NOV 1982
D'LOUHY & ASSOCIATES, INC.
CONSULTING ENGINEERS

Frank Shumer, Architect
10695 Beach Boulevard
Jacksonville, Florida 32216

Attention: Mr. George G. Gooden

Subject: Report of Exploratory Borings
Mayport Hurricane Moorings at Blount Island
Jacksonville, Florida
LETCO Job No. J-4033

Gentlemen:

Law Engineering Testing Company has completed a series of exploratory borings for the subject project. This report briefly outlines our exploratory techniques and presents the data obtained.

We are pleased to be of service on this phase of your project. If you have any questions concerning this report or desire assistance in evaluating the data, please contact us.

Very truly yours,

LAW ENGINEERING TESTING COMPANY

James A. Horton
James A. Horton, P.E.
Senior Geotechnical Engineer
Registered, Florida 23315

Lewis E. Hay (JAH)
Lewis E. Hay
Engineering Geologist

Distribution: Frank Shumer, Architect (2)
D'loughy & Associates (1)

JAH/LEH:/kk

FIELD EXPLORATION

As shown on the Site Location and Field Exploration Plan, the site of the borings is located in the old St. Johns River channel on the northwest side of Blount Island in north Jacksonville, Florida. For this exploration three soil test borings were made to the designated depth of 50 to 55 feet each below the existing water surface at the locations requested by your office. The attached Site Location and Field Exploration Plan also shows the locations of all the borings. The borings were located in the field by our drill crew using tape measurements from features such as the existing dolphins. The water surface elevations at the boring locations were established by measuring the level of water relative to the Blount Island Wharf at the time of drilling.

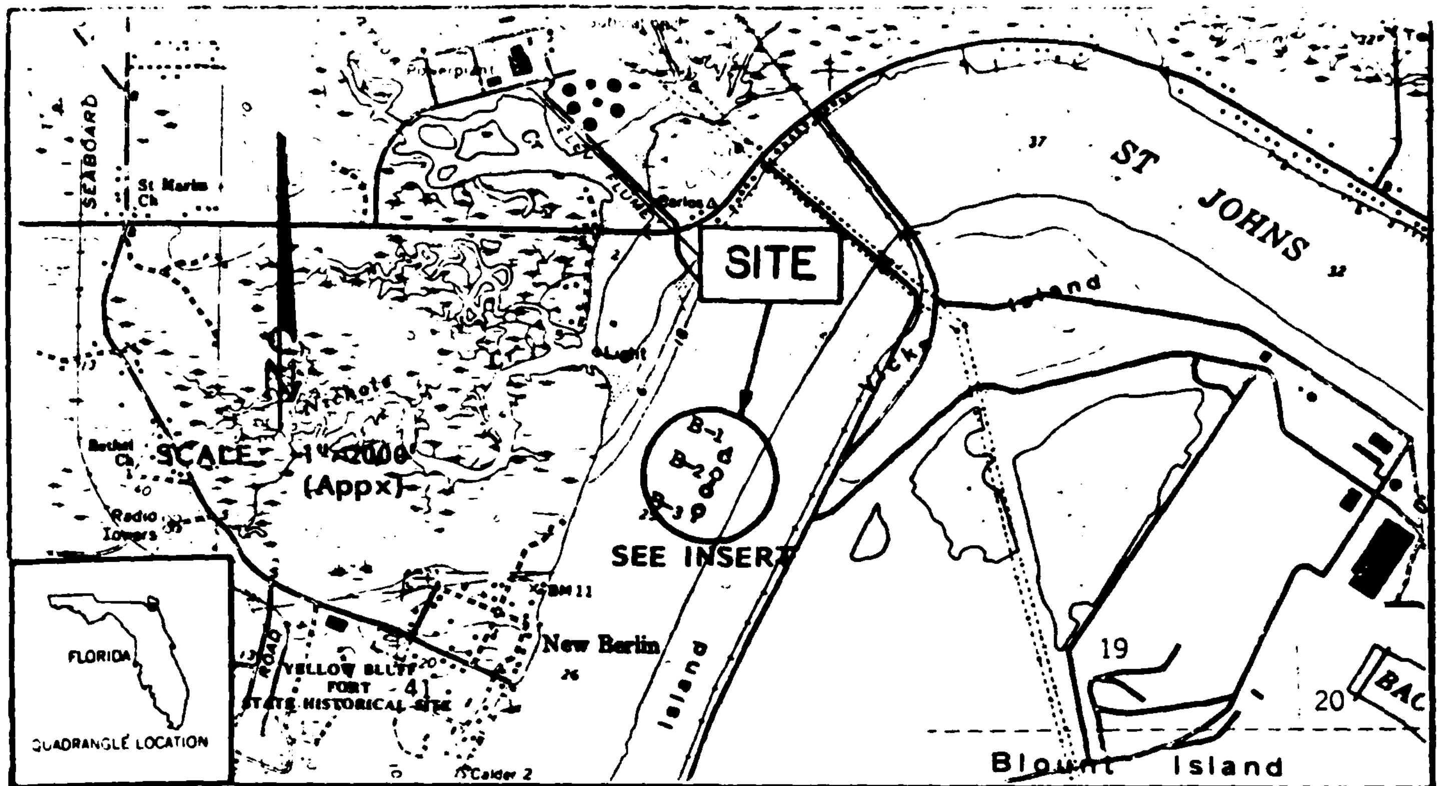
Soil Test Borings

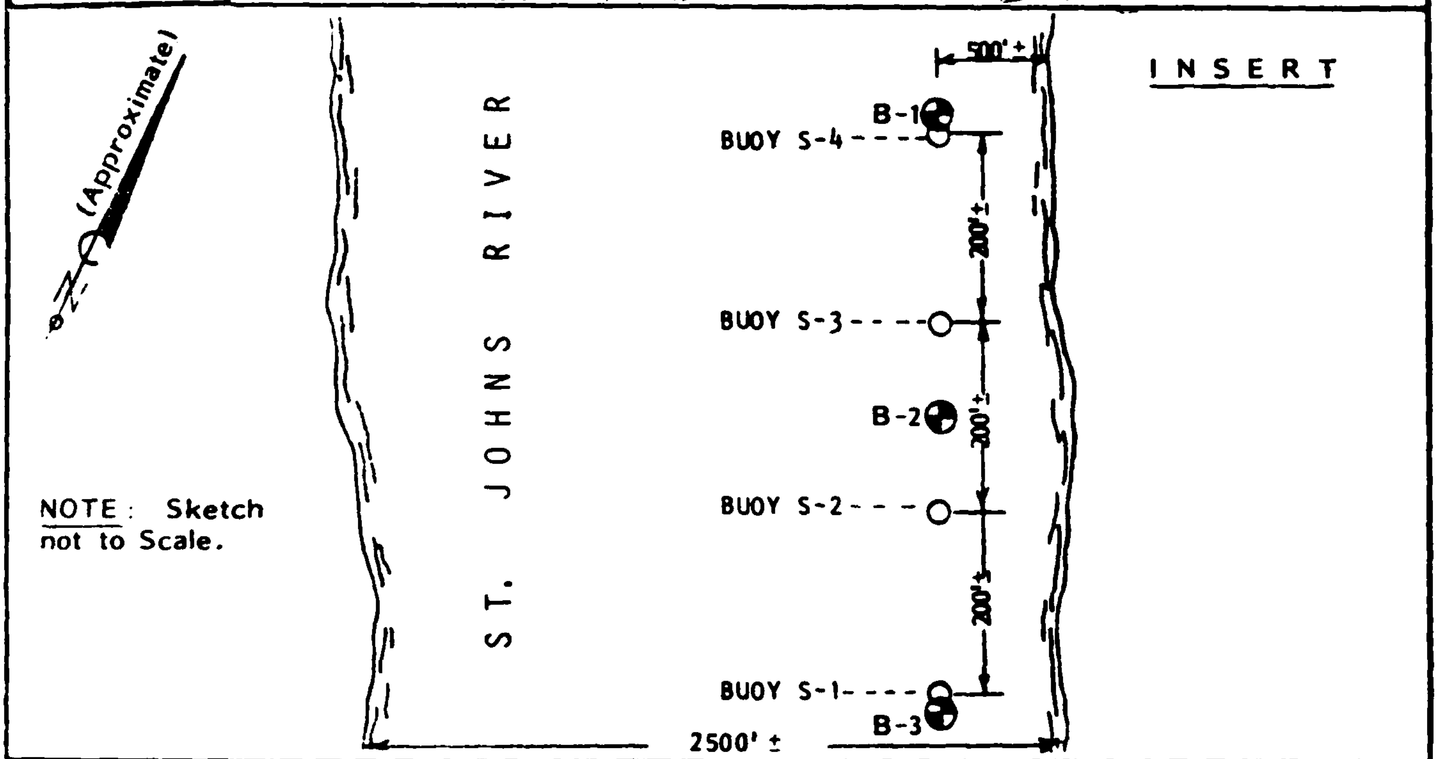
The soil test borings were made in general accordance with ASTM D-1586, "Penetration Test and Split-Barrel Sampling of Soils." A three-inch I.D. casing was initially extended from slightly above the expected high water level to below river bottom. A rotary drilling process was subsequently used and bentonite drilling fluid was circulated in the bore holes to stabilize the sides and flush the cuttings. At regular intervals, the drilling tools were removed and soil samples were obtained with a standard 1.4 inch I.D., 2.0 inch O.D., split-tube sampler. The sampler was first seated six inches and then driven an additional foot with blows of a 140 pound hammer falling 30 inches. The number of hammer blows required to drive the sampler the final foot is designated the "Penetration Resistance."

Representative portions of the soil samples, obtained from the sampler, were placed in glass jars and transported to our laboratory. The samples were then examined by an engineer in order to verify the field classifications.

For detailed information about the soil conditions encountered at each boring location, the attached Test Boring Records should be consulted. The horizontal stratification lines on these records indicate the approximate boundary between soil types and in some cases the transition may be gradual. It should be understood when reviewing these records that the soil conditions could vary between the boring locations.

ATTACHMENTS





LEGEND

Soil Test Boring Location

References:

1) Eastport Quadrangle, Florida; 1964, Rev. 1981 Topographic Map U.S. Geological Survey
2) Location Map Dlouhy & Associates, Inc. Project No. 8020.0 Dated 5/07/80

LAW ENGINEERING
TESTING COMPANY
Jacksonville, Florida

SITE LOCATION & FIELD EXPLORATION PLAN

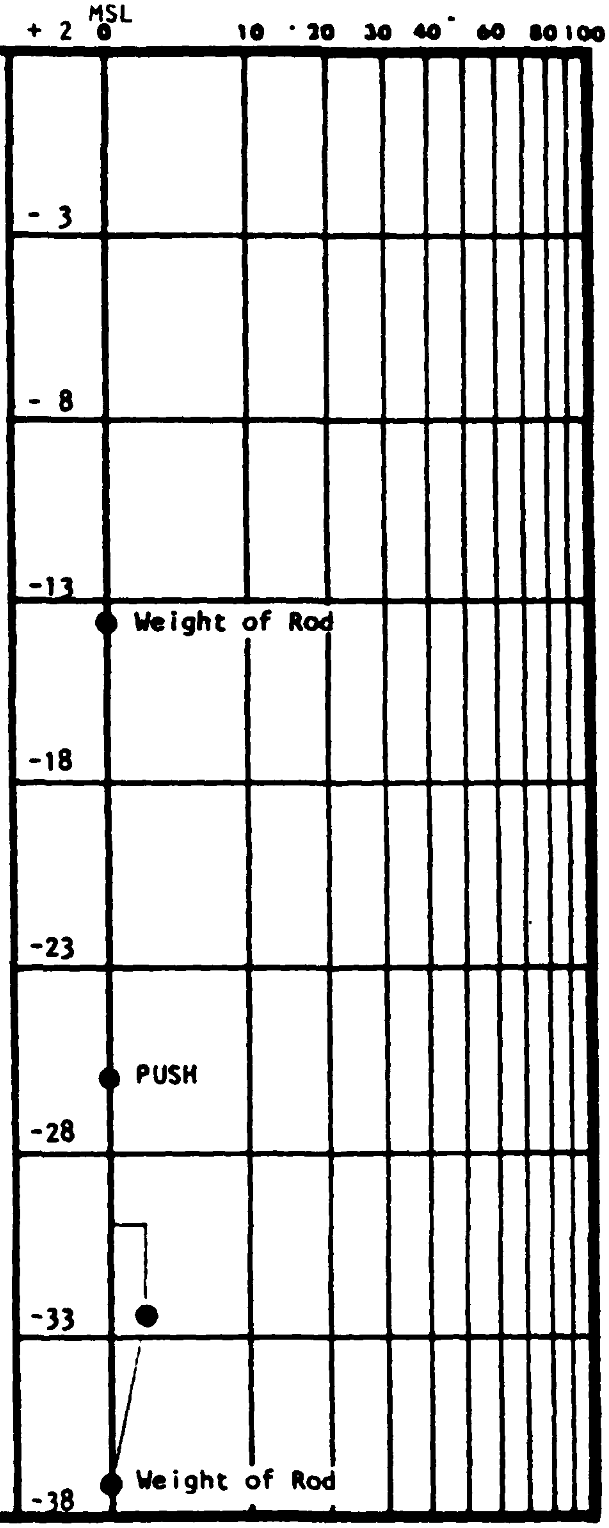
Mayport Hurricane Moorings at Blount Island
Jacksonville, Florida

DRAWN: DED	DATE: 10/27/82	SCALE: As Shown
CHECKED: JAH	JOB NO: J-4033	

DEPTH FT	DESCRIPTION
0.0	WATER
13.0	VERY SOFT dark grey SILT with sand seams in lower 4 feet
32.0	VERY LOOSE grey fine SAND with silt seams and layers
40.0	

ELEV., FT. MSL

• PENETRATION BLOWS PER FT



PAGE ONE OF TWO (1 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D 1586
CORE DRILLING MEETS ASTM D 2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT.

UNDISTURBED SAMPLE

% ROCK CORE RECOVERY

WATER TABLE, 24 HR

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

BORING NO. B-1

DATE DRILLED 10/18/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO.

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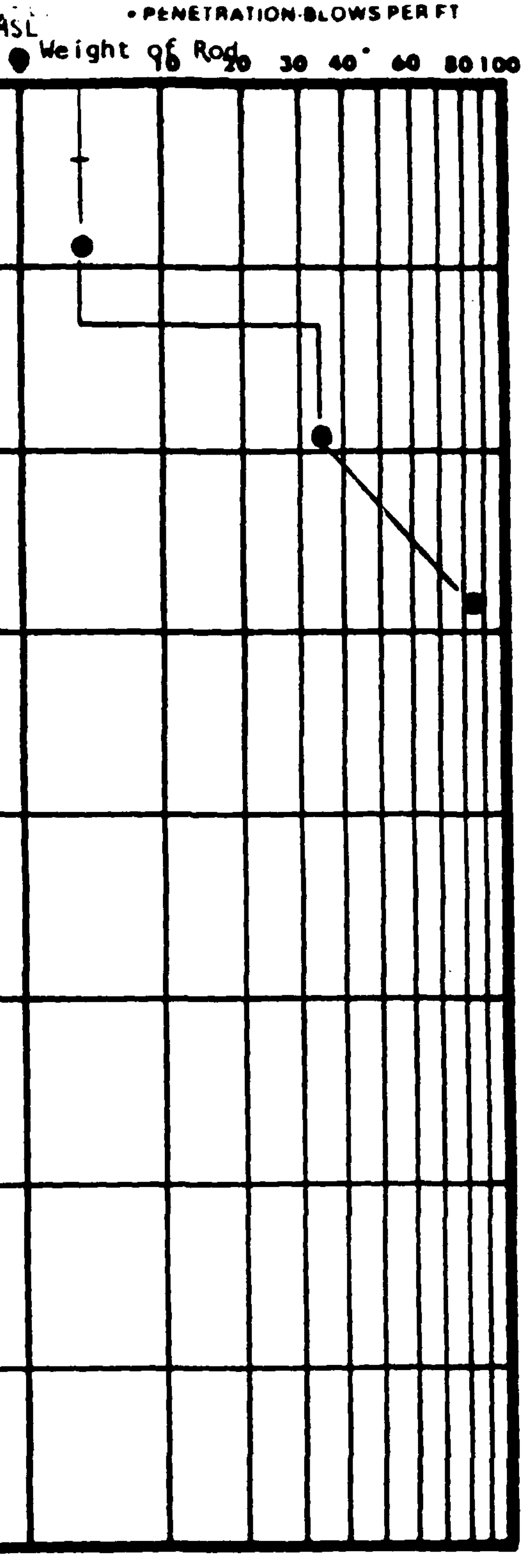
DEPTH FT	DESCRIPTION	ELEV ASL
40.0	SOFT dark blue-grey slightly clayey SILT	-38
42.0	SOFT brown slightly sandy SILT	-43
46.5	Brown cemented to slightly cemented silty fine SAND with zones of brown slightly silty fine sand (Silty sandy LIMESTONE)	-48
55.0	BORING TERMINATED	-53

NOTE: Borehole cased to 35 feet.



PAGE TWO OF TWO (2 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D 1586
CORE DRILLING MEETS ASTM D 2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT.

UNDISTURBED SAMPLE

% ROCK CORE RECOVERY

WATER TABLE, 24 HR.

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

BORING NO. B-1

DATE DRILLED 10/18/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO.

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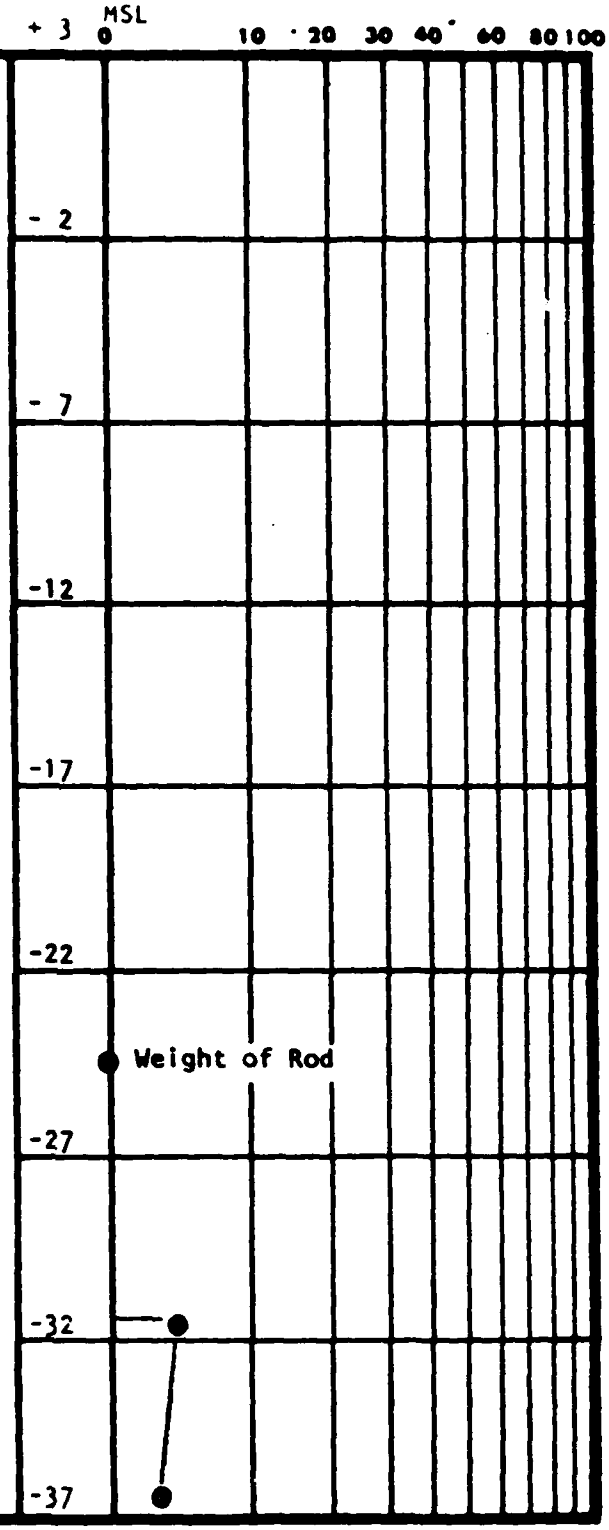
DEPTH FT	DESCRIPTION	ELEV. FT.
0.0	WATER	+ 3
6.0	VERY SOFT dark grey SILT with sand seams in lower 6 feet	
34.5	VERY LOOSE grey fine SAND with silt seams	
40.0		

• PENETRATION BLOWS PER FT



PAGE ONE OF TWO (1 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D 1586
CORE DRILLING MEETS ASTM D-2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT

UNDISTURBED SAMPLE

% ROCK CORE RECOVERY

WATER TABLE, 24 HR.

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

BORING NO. B-2

DATE DRILLED 10/19/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO.

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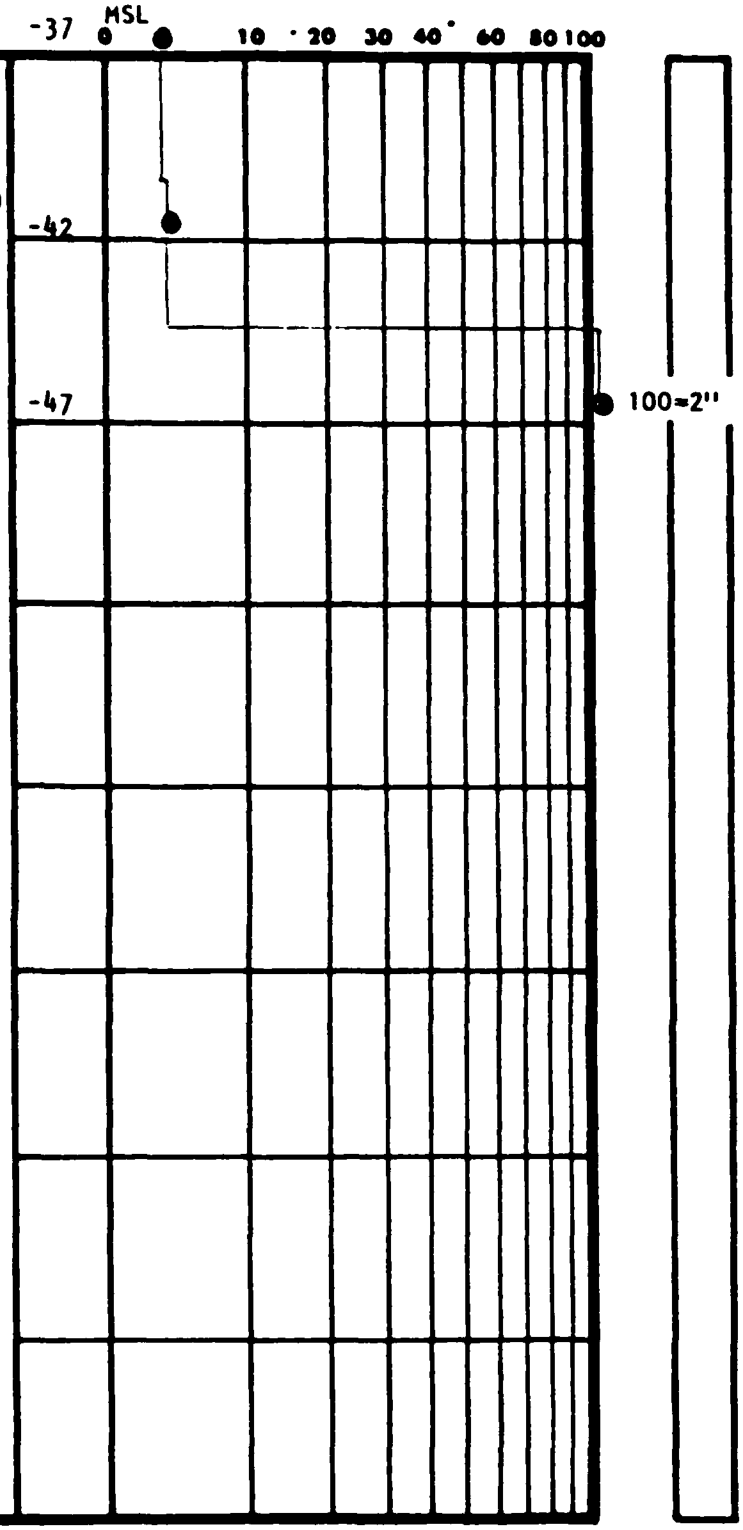
DEPTH FT	DESCRIPTION		ELEV., FT. MSL
40.0	VERY LOOSE grey fine SAND with silt seams		-37
43.5	VERY SOFT blue-grey slightly clayey	(1)	
44.5	VERY SOFT to SOFT green-brown slightly sandy slightly silty CLAY		-42
47.5	Brown well cemented silty fine SAND (Limestone)		
50.0	BORING TERMINATED		-47



NOTE: Borehole cased to 35 feet.

(1) SILT with sand seams

PAGE TWO OF TWO (2 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D 1586
CORE DRILLING MEETS ASTM D 2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT

UNDISTURBED SAMPLE

% ROCK CORE RECOVERY

WATER TABLE, 24 HR.

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

BORING NO. B-2

DATE DRILLED 10/19/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO

DEPTH FT	DESCRIPTION		ELEV. FT.	• PENETRATION-BLOWS PER FT
0.0	WATER		+ 2, MSL 0, - 3, - 8, -13	10 20 30 40 60 80 100
19.0	VERY SOFT grey SILT with sand seams in lower 3 feet		-18, -23, -28	Weight of Rod; PUSH
32.5	VERY FIRM grey fine SAND with some fine shell		-33	
37.0	VERY SOFT blue-green CLAY with	(1)		
38.0	Brown cemented silty fine SAND (Silty sandy LIMESTONE)		-38	
40.0				

(1) some sand seams

PAGE ONE OF TWO (1 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT.

UNDISTURBED SAMPLE

% ROCK CORE RECOVERY

WATER TABLE, 24 HR.

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

BORING NO. B-3

DATE DRILLED 10/13/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO.

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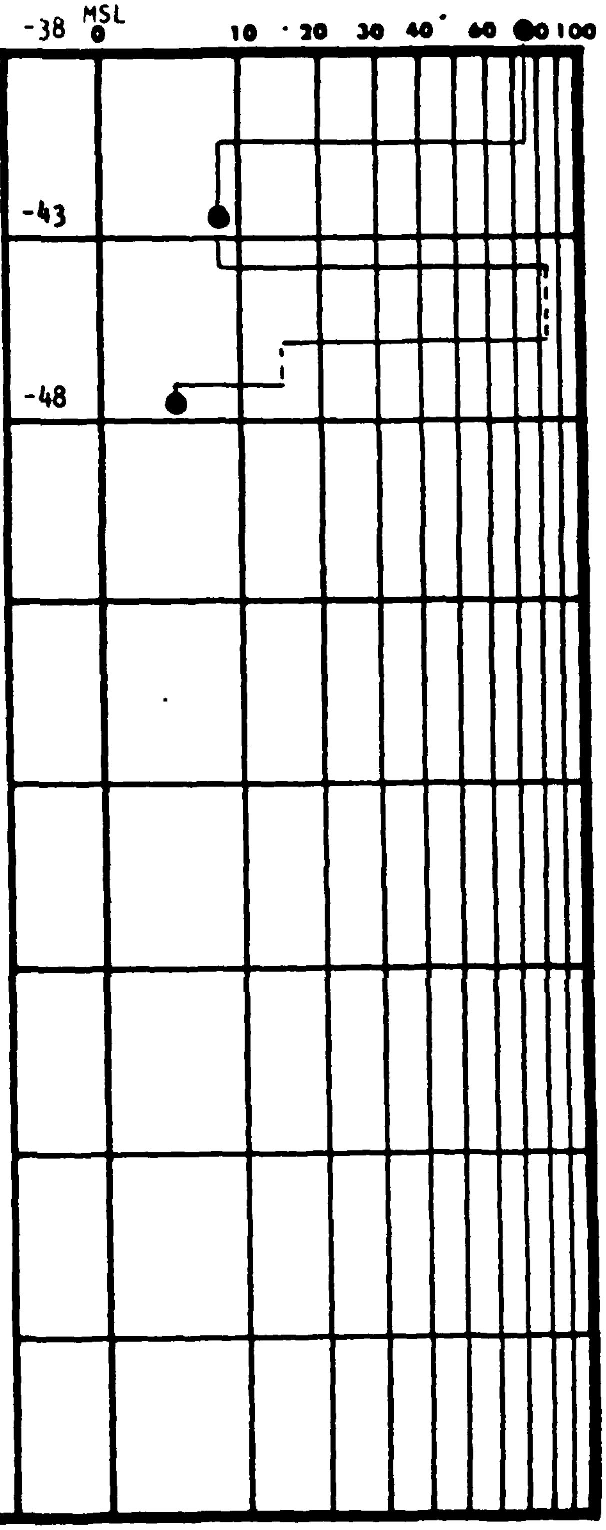
FT	DESCRIPTION	
40.0	Brown cemented silty fine SAND (Silty sandy LIMESTONE)	
42.5	LOOSE brown slightly silty fine SAND with limestone fragments	
46.0	Brown well cemented silty fine SAND (Silty sandy LIMESTONE)	
48.0	VERY FIRM grey fine SAND	
49.0	Brown slightly cemented silty fine	(2)
50.0	BORING TERMINATED	



NOTE: Borehole cased to 35 feet.

(2) SAND (Silty sandy LIMESTONE)

PAGE TWO OF TWO (2 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT

UNDISTURBED SAMPLE
% ROCK CORE RECOVERY
WATER TABLE, 24 HR.
WATER TABLE AT TIME OF DRILLING
LOSS OF DRILLING WATER

BORING NO. B-3
DATE DRILLED 10/13/82
JOB NO. J-4033

LAW ENGINEERING TESTING CO

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KEY TO SOIL CLASSIFICATION

Correlation of Penetration Resistances with Relative Density and Consistency

	NO. OF BLOWS, N	RELATIVE DENSITY
SANDS AND GRAVELS		
	0 - 4	Very Loose
	5 - 10	Loose
	11 - 20	Firm
	21 - 30	Very Firm
	31 - 50	Dense
	Over 50	Very Dense
	NO. OF BLOWS, N	**CONSISTENCY**
SILTS AND CLAYS		
	0 - 2	Very Soft
	3 - 4	Soft
	5 - 8	Firm
	9 - 15	Stiff
	16 - 30	Very Stiff
	31 - 50	Hard
	Over 50	Very Hard

Particle Size Identification (Unified Classification System)

Boulders -	Diameter exceeds 8 inches
Cobbles -	3 to 8 inches diameter
Gravel:	Coarse - 3/4 to 3 inches in diameter
	Fine - 4.76 mm to 3/4 inch diameter
Sand:	Coarse - 2.0 mm to 4.76 mm diameter
	Medium - 0.42 mm to 2.0 mm diameter
	Fine - 0.074 mm to 0.42 mm diameter
Silt and Clay:	Less than 0.07 mm (Particles cannot be seen with naked eye)

MODIFIERS

The modifiers provide our estimate of the amount of fines (silt or clay size particles) in the soil sample.

APPROXIMATE FINES CONTENT	MODIFIERS
5% Fines 12%	Slightly silty or slightly clayey
12% Fines 30%	Silty or clayey
30% Fines 50%	Very silty or very clayey

END
DTIC
7-86